STUDY OF OVERTAKING BEHAVIOUR ON TWO LANE HIGHWAYS

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By
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CERTIFICATE

24.12.92
B

This is to certify that the thesis "STUDY OF OVERTAKING BEHAVIOUR ON TWO LANE HIGHWAYS" submitted by Vishwanath Jagid in partial fulfillment of the requirements for the degree of **Master of Technology** of the **Indian Institute of Technology, Kanpur**, is a bonafide research work carried out by him under my supervision and guidance. The work embodied in this thesis work has not been submitted elsewhere for the award of a degree.

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To the remotest corner of my heart, I can not visualize the epitomizing of my thesis work without the help of some of my near and dears.

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ABSTRACT

The overtaking on two-lane roads is highly complex, involving time, speed and distance variables. However, basically it is greatly restricted by both available sight distance and traffic volume. The demand for overtaking is a function of the characteristics of drivers and vehicles. Demand also varies in time and space.

The Indian traffic system is extremely heterogeneous and highly complex and it is very difficult to express the speed flow relationships unless interactions between vehicles are studied in detail, for which the formulation of realistic simulation models is imperative. The traffic interaction model of the simulation process describes the interaction between the vehicles while moving on the road system.

To calibrate the various components involved in the overtaking manoeuvre, a special Video Instrumentation System was used for recording by C.R.R.I. New Delhi. For recording, Maruti Van is used as Test Vehicle, which is fitted with video system, digital odometer and radar speed meter. For this analysis, 25 cassettes for plain and 18 cassettes for rolling terrain are available.

The overtaking manoeuvres are classified in two categories (i) Flying Overtaking (ii) Accelerative Overtaking. The recorded video tapes are analysed in the laboratory to get primary data for

each overtaking manoeuvre. The events are recorded on the proforma. A computer program is developed to locate various errors and inconsistencies in the recorded data. After complete validation of the data, the files are merged to make two groups one for plain terrain and other for rolling terrain.

The analysis is carried out by aggregating all types of overtaking vehicles. The primary data is used in a computer program which determines the frequency distribution of the eight derived parameters which quantify the overtaking manoeuvre. This information is input for a display program which provide online graphic display of different parameters. The values of all the derived parameters are analysed separately for time gap and space gap measurements in plain and rolling terrains.

The distributions of various derived parameters (aggregated) show wide dispersion. Hence the derived parameters are studied for six vehicle types. Mean standard deviation and skewness coefficient are computed separately for flying and accelerative overtaking operation both in plain and rolling terrains. Gap statistics are further expressed both for time and space measurements.

The frequency distributions for the accepted and rejected gap by different types of vehicles, both for flying and accelerative overtaking manoeuvres, are determind. For this analysis Maruti Van is being overtaken by other vehicles. The probability of accepting

a gap is determined from the frequency distributions of accepted and rejected gaps. Based on the observed proportion of acceptance for different gap sizes, a mathematical relationship is established to estimate the probability of overtaking for a gap size. The probability of gap acceptance is considered to follow a second degree polynomial relationship with gap size.

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1. INTRODUCTION

1.1 LEVEL OF SERVICE FOR TWO-LANE HIGHWAYS

Although many measures of level of service for two-lane highways have been developed there does not yet appear to be any international agreement regarding a specific measure. Nor does there appear to be a clear formulation of the two-lane highway problem according to the World Road Congress (XVIIIth 1987). However, the lack of consensus is not surprising given the complex nature of traffic flow on two-lane highways.

Evolution of level of service measures can be traced through the three Highway Capacity Manuals (HCM).

The 1950 Highway Capacity Manual (HRB 1950) represented the consolidation of three decades of previous research, some of which is still pertinent to two-lane highways today. Although the manual stated that the most significant index of traffic congestion for different volumes was the overall speed, the manual also recognized passing opportunities as an index of congestion. The 1950 HCM defined the passing opportunities index as:

> " the availability of opportunities for vehicles to overtake and pass slower vehicles in the same direction. The ratio of the number of passings required per mile of highway for drivers to maintain their desired speeds, to the number of passing that they can eventually perform, is a measure of traffic congestion."

The overtaking manoeuvre on two lane highway is highly complex involving time, speed, and distance variables. Basically it is also greatly restricted by both available sight distance and traffic volume.

The 1965 Highway Capacity Manual (HRB 1965) provided more flexibility than the 1950 HCM by introducing a range of levels of service and corresponding service volumes. Six levels of service A to F were defined with operating speed as the main description in the 1965 HCM with the level of service E corresponding to capacity conditions. In addition to speed being an inadequate indicator of level of service, the changing relationship between operating speed and volume to capacity (v/c) ratio (which defined level of service regions) has exacerbated the problem since the manual was introduced.

Level of service on two-lane highways in the 1985 Highway Capacity Manual (TRB 1985) is described by three parameters: (i) average travel speed (ii) percent time delay (iii) capacity utilization. However, percent time delay is the primary measure of service and is defined as the average percent of time that all vehicles are delayed while travelling in platoons due to their inability to pass. While the 1985 HCM introduces a quality of service criteria that is more sensitive than speed variations in the traffic flow and more accurately reflects the perceived freedom to manoeuvre than the 1965 HCM it cannot be used to measure the impact of auxiliary lanes such as passing lanes on level of service.

The opportunity for overtaking is a function of the supply of overtaking opportunities provided by highway geometry and gaps adequate for overtaking in the oncoming traffic stream. The supply of overtaking opportunities is more or less fixed when compared to the demand for overtaking which is determined by the characteristics of drivers and vehicles and varies in time and space. The demand for overtaking is a function of the characteristics of drivers and vehicles. Demand also varies in time and space, for example on level terrain autos, recreational vehicles and trucks generally travel closer to the same speed and are not competing or interacting with each other. The supply of overtaking opportunities is determined by the percentage of highway length with no passing zones (Morrol,1988). This in turn is a function of sight distance as determined by horizontal and vertical geometry.

1.2 BACKGROUND

The Indian traffic system is extremely heterogeneous and highly complex and it is very difficult to express the speed flow relationships unless interactions between vehicles are studied in detail, for which the formulation of realistic simulation models is imperative.

The first phase of the development of Traffic Simulation model for Indian traffic was completed in 1985. To further improve the development of the Simulation Models, a study was initiated in

1988 under sponsorship of Ministry of Surface Transport. This study is being implemented jointly by C.R.R.I. New Delhi and I.I.T. Kanpur.

The traffic interaction model of the simulation process describes the interaction between the vehicles while moving on the road system. The interaction process depends upon the driver and vehicle characteristics. To calibrate the various components involved in the overtaking manoeuvre, it is planned to record the pattern of the driver/vehicle behaviour on the road system. A large scale video recording of the overtaking operations was carried out by C.R.R.I. New Delhi during January to July 1992. The recording is done with an instrumented vehicle that captures various aspects of overtaking manoeuvre.

1.3 OBJECTIVES OF THE STUDY

This work involves extraction of data from the recorded video cassettes and analysis of overtaking manoeuvres. The objectives of this study are:

(i) To identify the events involved in the overtaking process which may be of interest in the development of the simulation model, and to extract data from the recorded video cassettes.

(ii) To study parameters that can be derived from the overtaking process and to estimate their distributions.

(iii) To estimate the probability of overtaking as a function of gap size for various types of vehicles.

2. LITERATURE REVIEW

2.1 INTRODUCTION

The overtaking and passing manoeuvre on two-lane roads is highly complex, involving time, speed and distance variables. However, basically it is greatly restricted by both available sight distance and traffic volume. If the traffic volume increases or the amount of available sight distance decreases, then the number of acceptable passing opportunities decreases causing an overall reduction in average speed on the road.

For a driver to initiate and complete a passing manoeuvre he must be able to judge whether it is safe to do so. The most important decision he must make is whether there is sufficient clear roadway ahead so that he may travel in the opposite lane until his position is ahead of the vehicle he wishes to pass. .

2.2 EARLIER STUDIES

The first study which dealt with the size of gap acceptable by the driver for passing manoeuvre was done by Greenshields(1935) using roadside sequence photography. He found that the median gap size was 30 seconds and that 20 percent of the drivers passed with gaps less then 17 seconds and 10 percent with gaps less then 12 seconds. This data did not give any information on passing thresholds (the time gap accepted by 50 percent of the drivers).

Forbes and Matson(1939) reported that 20 percent of the drivers who passed with an oncoming car in view passed with a safety margin of one second or less and 10 percent actually forced

the oncoming car to give way. They also found that shorter gaps were accepted by drivers in areas where short sight distances prevail. Whedon(1951) found that only 1 to 5 percent of the passes observed were initiated with 1000 feet or less sight distance and only 10 percent completed with less than 500 feet of sight distance.

One of the most complete studies on passing judgment was carried out by Crawford(1963) in England. Of the 251 passing opportunities presented to his subjects, 117 were accepted. By plotting the average smallest gap accepted and the average largest gap refused as a function of lead-car-oncoming-car closing rate, he was able to obtain a threshold region and an estimate of threshold passing distance (the distance at which 50 percent of the drivers passed) as a function of closing rate. That drivers do respond to some degree to closing rate is clear from the apparently linear relationship between closing rate and threshold distance.

Crawford supplemented his findings by obtaining passing threshold data on the highway. The passing thresholds in this case, for the same type of cars, were about one second longer. The safety margin (time from completion of pass to meeting of oncoming car) average 1.5 seconds on the highway as compared to 0.6 second in the controlled study.

Bjorkman's(1963) findings suggest that by holding lead-car speed constant as the oncoming-car speed increases, drivers will accept smaller gaps; and when closing rate is held constant,

smaller gaps will be accepted when the oncoming car is going faster than the lead car. These findings point out that while drivers do respond to closing rate to some degree, their behavior is more closely related to their own speed at the start of passing opportunity.

In an observational study on two-lane rural roads, Farber,et al.(1967), found that in the oncoming-car limited accelerative passing situations, the likelihood that a driver will pass increases monotonically with available passing distance up to 3000 feet. However, the greater the speed of the car, the less likely the driver is to accept a given passing opportunity (available passing distance). The median passing opportunity distance accepted ranged between 1600 and 2500 feet depending on lead-car speed. Reaction time and safety margin also increased as available passing distance increased.

In the same study, it was found than in oncoming-car limited passes, 5 percent of drivers accepted hazardous passing opportunities (available passing distance of less than 1000 feet) and at least 25 percent rejected safe passing opportunities.

Both Normann(1939) and Whedon(1951) report data on the oncoming gaps accepted by drivers where the limiting factor is not an oncoming car, but a sight distance restriction. These data were similar to that obtained in other studies where an oncoming car was the limiting factor; hence, driver behavior seems to be dependent only on the available distance.

Farber,et al., found that in oncoming-car limited passes drivers can judge between their own and oncoming-car to within ±20 percent 95 percent of the time at distances between 1000 and 3000 feet.

In a study conducted for the bureau of Public Roads(1967), it was found that drivers are relatively good judges of available distance to an oncoming vehicle, lead vehicle, no-passing zone or sight distance restriction but poor judges (at speed ranging from 30 to 60 mph), of oncoming-car speed or crossing rate unless the distances were quite small. In both experimental studies on closed roads and observational studies of actual passing practices on public highway, Farber,et al., found that drivers display no sensitivity to oncoming-car speeds or closing rates. Drivers made passing decision strictly on the basis of the distance to the oncoming car and their own speed prior to the pass. The inability of drivers to judge critical velocity variables is a major source of passing-decision error and affects both the safety and throughput on two-lane rural highways.

2.3 SWEDISH STUDY ON OVERTAKING BEHAVIOUR

Grabe and Stotz (1968) used cameras and a time recorder to measure overtaking times, overtaking distances, headways and accepted gaps. They reported on about 1400 overtakings by passenger cars only and concluded that overtaking distance and gap accepted size increased as the overtaken vehicle's speed increased.

Ahman (1968) used a camera mounted on the roof of a passenger car. Ahman viewed both forward and rearward at the same time by using two mirrors affixed near the lens. One frame was exposed by the camera every 15 m of travel by the last vehicle and the time was recorded by a constant speed penrecorder.

Ahman analysed 1536 overtaking around a passenger car travelling at 60 km/h and 466 overtakings around a car travelling at 80 km/h. Some 66 percent of these overtaking were flying and 16 percent were completed with an oncoming vehicle in view. Only two overtakings in 2002 were aborted and from this Ahman concluded that the point of no return is at an early stage in the manoeuvre.

Ahman classified the overtaking according to the overtaking vehicle type. He found that overtaking time were virtually independent of vehicle type. He found that overtaking times and distances were dependent upon the speed of the overtaken vehicle and to some extent by the design standard of the road. Ahman recorded overtaking time and distance around vehicles travelling at 80 km/h.

The same techniques were used by Ahman (1972) in a follow-up study. In this study Ahman used a truck 9 m long and a truck and trailer 20 m long as the test vehicles. Ahman analysed 591 overtakings around a 20 m vehicle. Of these, 25 percent were flying and 25 percent were completed with an oncoming vehicle in view. These percentages differ from the percentage given by Ahman (1968) in his earlier study.

Ahman (1972) concluded that overtaking distances were 25-50 m longer for overtaking around 9 to 20 m vehicles than around passenger cars. Ahman (1968 and 1972) did not list mean headways at start and end of the manoeuvre.

2.4 AUSTRALIAN STUDY ON OVERTAKING BEHAVIOUR

An experimental program was undertaken by Austraian Road Research Board (Troutbeck,1982) to investigate the desires and abilities of drivers to overtake vehicles of various dimensions. This had the broad objective of determining the effects of long vehicles in the traffic stream.

The manoeuvre is assumed to commence when the overtaking vehicle first crosses the center line and is assumed to be completed when the vehicle is clear of the opposing traffic lane. The overtaking manoeuvre was divided into three sections. The first section extend from the start of the manoeuvre until the rear of the overtaking vehicle is alongside the rear of the overtaken test vehicle. The second section extends from the end of the first section until the rear of the overtaking vehicle is alongside the front of the overtaken vehicle. The third section extends from the end of the second section until the completion of the manoeuvre. The overtaking manoeuvre was categorised according to the following condition:

(a) Flying or accelerative: In an accelerative overtaking the overtaking vehicle slows to the speed of the overtaken vehicle before commencing the overtaking

manoeuvre. However, a flying overtaking does not require the overtaken vehicle to slow down before overtaking.

(b) Single or multiple: A multiple overtaking occurs when a vehicle overtakes more than one vehicle.

(c) Car or commercial vehicle overtaking: A commercial vehicle is defined as one having three or more axles or having dual wheels on one axle.

(d) Oncoming vehicle or the road geometry restricts the forward vision of the overtaking driver.

This provides for 16 classifications.

A passenger car was used for the initial tests. The subsequent experimental program used a semi-trailer which could have various lengths between 11.2 and 17.3 m. The length of the research vehicles varied from 5 to 21 m. The research vehicle were fitted with video equipment together with a digital speedo-odometer and a radar speed meter.

Video cameras were fixed to the front and rear of the test vehicle. By affixing a mirror near the lens, the rear video camera could view past the edge of the mirror rearward and via the mirror to the right of the test vehicle at the rear. A similar arrangement enabled the front camera to view forward and to the right at the front. The rear camera was mounted underneath the tray of the trailer.

The video effects generator was used to switch from one camera signal to the signal from the other camera. When the output

signal from the effects generator was viewed on a monitor, the upper portion of the screen was from the rear camera and the lower portion from the front camera.

A modified video clock enabled a series of digits to be superimposed onto the video image. These digits gave time of day, the speed of and distance travelled by the test vehicle as measured by the digital speed-odometer, and the speed of the oncoming and overtaking vehicles as measured by the radar speedmeter. The video signal was displayed on a monitor. When the video tape was replayed, four views were recorded. The digital information gives:

(a) The relative speed of the overtaking vehicle at that instant (km ph).

(b) The speed of the test vehicle at that instant (km ph).

(c) The time of day (hr. min. sec.).

(d) The odometer reading for the test vehicle (meters).

The most important outcome of this study was a series of regression equations which relate the mean and variance of overtaking performance parameters (overtaking time, overtaking distance etc.) to the length and speed of the overtaken vehicle for various overaking manoeuvre types (flying, accelerative, single, multiple etc.).

3. FIELD DATA GENERATION

3.1 INTRODUCTION

Appropriate and adequate field data and observation are a pre-requisite for successful simulation modelling. Such data are essential for the following three phases of model development.

(i) Formulation of an accurate logic system to enable structuring an appropriate model.

(ii) Calibration of the logic based model.

(iii) Validation of the calibrated models, by cross-checking for accuracy of prediction against additional field data.

Field data generation and analysis occupy a key position in any plan of simulation model development. For the traffic interaction studies which involved study of vehicle interaction characterstic in the traffic stream, and called for high degree of precision, special Video Instrumentation System developed by Australian Road Research Board (ARRB,1982) alongwith essential ancilliaries, was used for recording.

3.2 VIDEO INSTRUMENTATION SYSTEM

3.2.1 COMPONENTS OF THE SYSTEM

The system consists essentially of the following main components:

(i) Video Camera

(ii) Video Recorder

(iii) Video Monitor

(iv) Video Splitter

(v) Video Timer

In addition to above main components depending upon the type of experiment, the system is supplemented with the following additional ancilliaries:

(vi) Digital-Odometer

(vii) Radar Speed Meters

3.2.2 DESCRIPTION OF MAIN COMPONENTS

(i) CAMERA: Cameras are required to take continuous picture of the movement of vehicles in the traffic. The cameras procured for the study are black and white type.

(ii) VIDEO RECORDER: The video recorder incorporates frame by frame movement of the tape. This unit is mainly for purpose of the survey data for which facility of frame by frame movement is necessary to locate accurately the timing of a particular traffic event.

(iii) VIDEO MONITOR: The monitor exhibits pictures during recording indicating the quality and coverage of the recording. It also serves as replay unit for data reduction and analysis.

(iv) VIDEO SPLITTER: Video splitter is a device which enables pictures taken by more than one camera to be recorded in a single frame. For example, if two cameras are used simultaneously and both the pictures are to be viewed, the splitter divides the monitor frame either vertically or horizontally into two parts. Similarly, if four cameras are used the frame could be divided into quadrants.

(v) VIDEO TIMER: The video timer superimposes digital indications for date and time on the picture frames in the recording system. Accurate timing is provided with the help of an all-electronic crystal controlled AC circuit. The time indication is given in hours, minutes, seconds and $1/10^{th}$ of a second.

(vi) DIGITAL ODOMETERS: These are rotopulser based instruments in which 'Rotopulser' transducer is attached to the speedometer cable. This transducer gives 1000 square wave pulses for each complete turn of the speedometer cable. As an example, if the shaft of the rotopulser rotates 'n' times for each kilometer of travel, there will be 1000 n pulses from the rotopulser per kilometer of travel.

The pulses from the 'Rotopulser' are fed into a gate which produce one new pulse when N pulses are received. These new pulses are counted and displayed on the instrument and can be sent to the video clock in a Binary Coded Decimal (BCD) format. A total of 1000 n/N pulses are recorded for 1 km of travel. If N is set to n, the display will be in kilometer and meter.

(vii) RADAR SPEED METER: Radar speed meter is used to detect the speed of a moving vehicle. The radar speed meter used for overtaking and crossing studies is of a different design specifically intended for mobile operation. It contains both the antenna and the read out in a single unit convenient to hold in hand or to fix inside a test car.

The information is transmitted to Binary Coded Display (BCD) and LED display of the speed in the radar. The BCD is also

taken to a video timer and superimposed as digital indication on the video picture for recording on the video tape. The instrumentation system is shown in Fig.3.1.

3.3 FIELD DATA COLLECTION PROCESS

For recording, Maruti Van is used as Test Vehicle, which is fitted with video system, digital odometer and radar speed meter. Two video cameras are fitted on the test vehicle. One camera is fitted near the driver facing the road and traffic in front of the test vehicle and another on the rear facing the road and traffic behind the test vehicle. The radar speed meter, for calculating the relative speed of oncoming vehicle with respect to the test vehicle, is fitted near the driver facing the traffic in front of the test vehicle. The speedometer of test vehicle is also connected to the video system. The whole system is kept in such a way that it is not visible to the drivers of the other vehicles in the traffic.

The driver of the test vehicle is instructed to drive at a speed as he would drive in the normal course. Whenever a vehicle catches up with the test vehicle from the rear, with a view to overtaking, its pictures are taken through the rear camera and recorded on the tape. At the same time the camera in the front takes pictures of the vehicles moving in the opposite direction. When the vehicle approaching from rear starts to overtake it accelerates and goes to the right side of the test vehicle, and there after comes in front of it and completes the overtaking. As soon as it comes in the field of vision of the front camera its

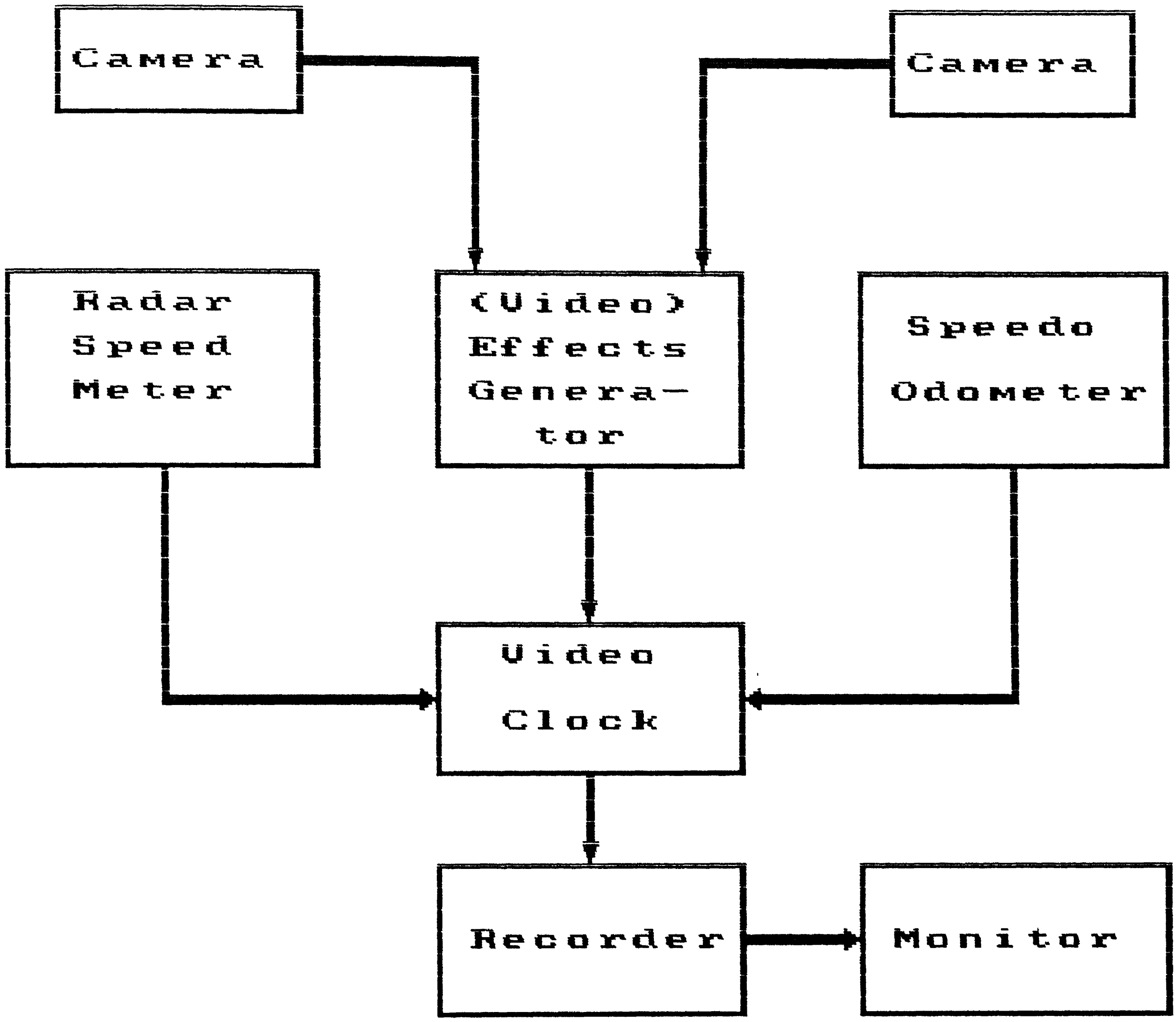


Fig. 3.1 — Instrumentation system

picture is recorded at the front. The speed of the overtaking vehicle is taken by the radar meter and recorded on the videotape. The distance travelled and the time taken by the test vehicle are also recorded on the tape.

3.4 EXPERIMENTAL DESIGN

The video recording of the overtaking operation was carried out by C.R.R.I. New Delhi with Maruti Van as the Test Vehicle. For this analysis, 25 cassettes for plain and 18 cassettes for rolling terrain are available. The recording with Truck as the test vehicle is to start soon. The road sections on which video recording was done are listed in Table 3.1.

TABLE 3.1 : RECORDING OF OVERTAKING OPERATIONS

(i) Plain Terrain

Tape 1	Agra - Aligarh - Debar Road
Tape 2	Agra - Gwalior Road
Tape 3	Agra - Gwalior Road
Tape 4	Aligarh - Sikandra - Rao Road
Tape 5	Aligarh - Sikandra - Rao Road
Tape 6	Barabanki - Faizabad Road
Tape 7	Delhi - Faridabad - Faval Road
Tape 8	Delhi - Jaipur Road
Tape 9	Gwalior - Shivpuri Road
Tape 10	Gwalior - Shivpuri Road
Tape 11	Lucknow - Barabanki Road
Tape 12	Lucknow - Barabanki Road
Tape 13	Lucknow - Kanpur Road
Tape 14	Lucknow - Kanpur Road
Tape 15	Lucknow - Raibareeily - Jai Road Road
Tape 16	Meerut - Delhi Road
Tape 17	Meerut - Muzafarnagar Road
Tape 18	Rahatgar - Sagar - Lalitpur Road
Tape 19	Shivpuri - Gwalior Road
Tape 20	Shivpuri - Gwalior Road
Tape 21	Sonipat - Panipat - Karnal Road
Tape 22	Sonipat - Panipat - Karnal Road
Tape 23	Sonipat - Panipat - Karnal Road
Tape 24	Sonipat - Panipat - Karnal Road
Tape 25	09 (No - M9)

(ii) Rolling Terrain

Tape 1	Ajmer - Beawer Road
Tape 2	Ajmer - Beawer Road
Tape 3	Ajmer - Kishangarh Road
Tape 4	Beawer - Bar - Beawer/ Ajmer - Kishangarh Road
Tape 5	Dehradun - Hardwar - Rishikesh Road
Tape 6	Dehradun - Hardwar - Rishikesh Road
Tape 7	Dehradun - Hardwar - Rishikesh Road
Tape 8	Dehradun - Hardwar - Rishikesh Road
Tape 9	Dehradun - Hardwar - Rishikesh Road
Tape 10	Dehradun - Hardwar - Rishikesh Road
Tape 11	Gwalior - Jhansi Road
Tape 12	Gwalior - Jhansi Road
Tape 13	Jhansi - Gwalior Road
Tape 14	Jhansi - Sagar Road
Tape 15	Jaipur - Ajmer Road
Tape 16	Nasirabad - Ajmer Road
Tape 17	Nasirabad - Ajmer - Nasirabad Road
Tape 18	Nasirabad - Kishangarh Road

4.1 DEFINITION OF AN OVERTAKING MANOEUVRE

The definition of various aspects of an overtaking manoeuvre are required if it is being planned to quantify the manoeuvre. The overtaking manoeuvre can be classified into following two categories:

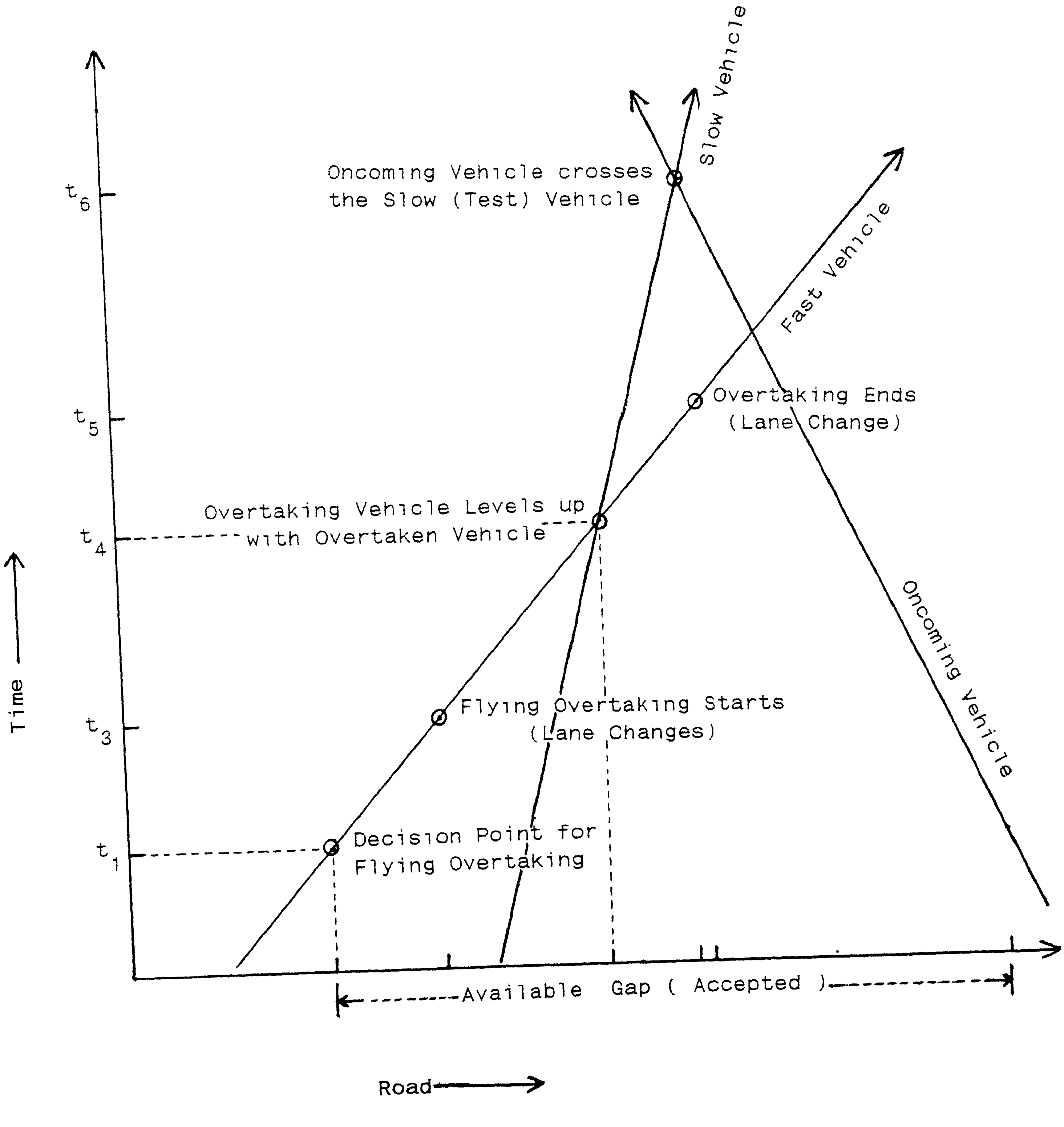
(i) Flying overtaking which does not involve the slowing down of the overtaking vehicle.

(ii) Accelerative overtaking in Which the overtaking vehicle slows down to the speed of the overtaken vehicle before the overtaking manoeuvre is commenced.

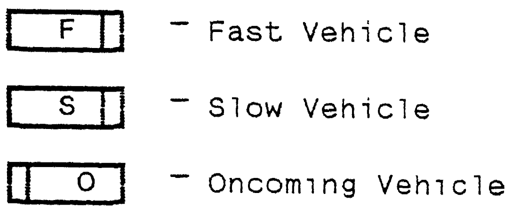
The various aspects of the flying and accelerative overtaking manoeuvres are illustrated in Figs. 4.1 - 4.2.

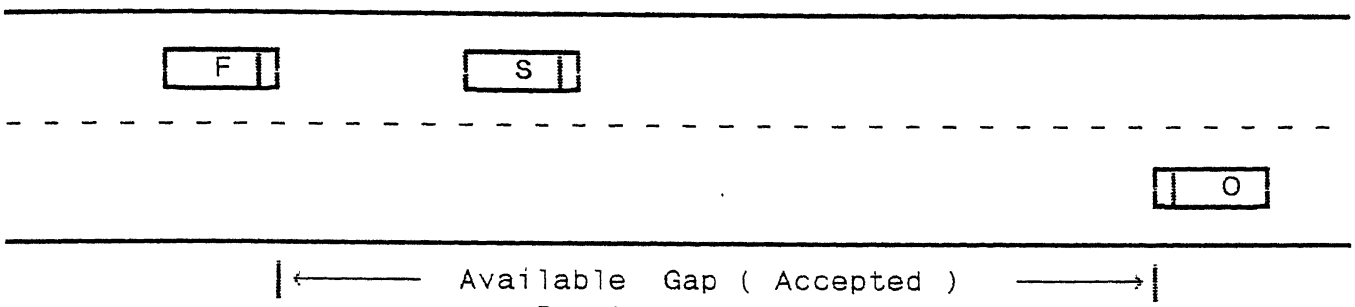
4.1.1 FLYING OVERTAKING

When a faster vehicle catches up with the slower vehicle the driver has an opportunity to perform the flying overtaking. The decision point for the flying overtaking is at the instant of catching up (time t_1) with slow moving vehicle. The available gap for the acceptance/rejection of the flying overtaking opportunity is the gap between the vehicle desiring to overtake and oncoming obstructions (vehicles or sight distance limitation). If the flying overtaking is accepted, the manoeuvre starts with the overtaking vehicle moving to the wrong lane (time t_3) and then overtaking and overtaken vehicles level up(time t_4). The overtaking vehicle, after passing, returns to its proper lane(time t_5). Time t_6 represents the instant when oncoming vehicle or sight obstruction crosses the test vehicle.



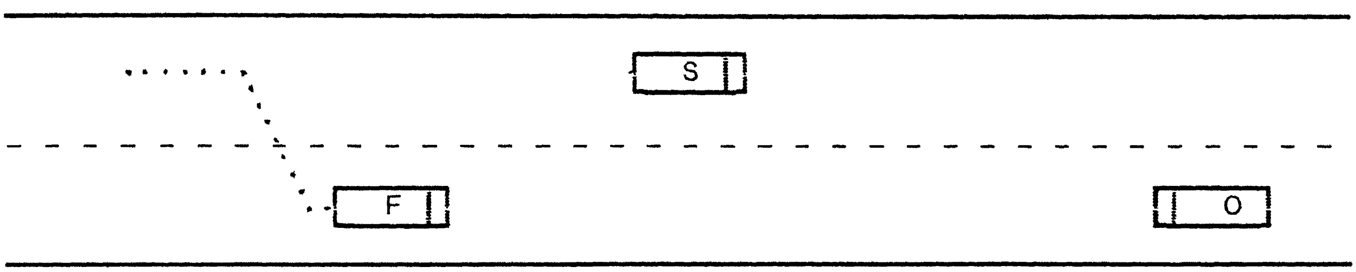
FLYING OVERTAKING MANOEUVRE





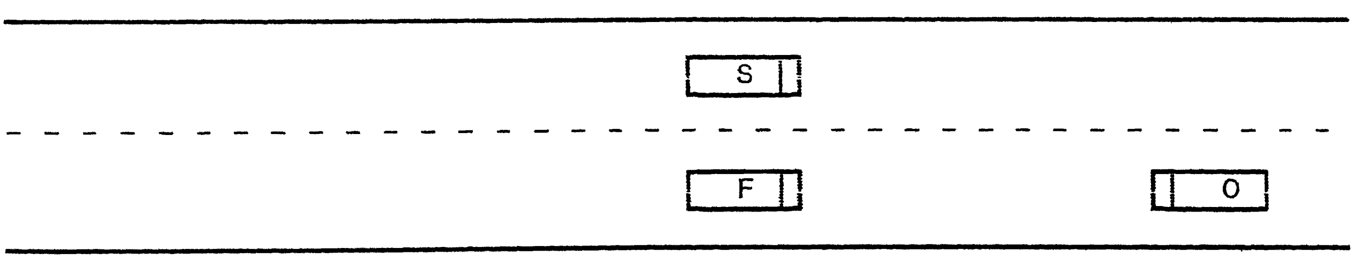
Position at time t_1

Fast Vehicle Catches up (Decision Point for Flying Overtaking)



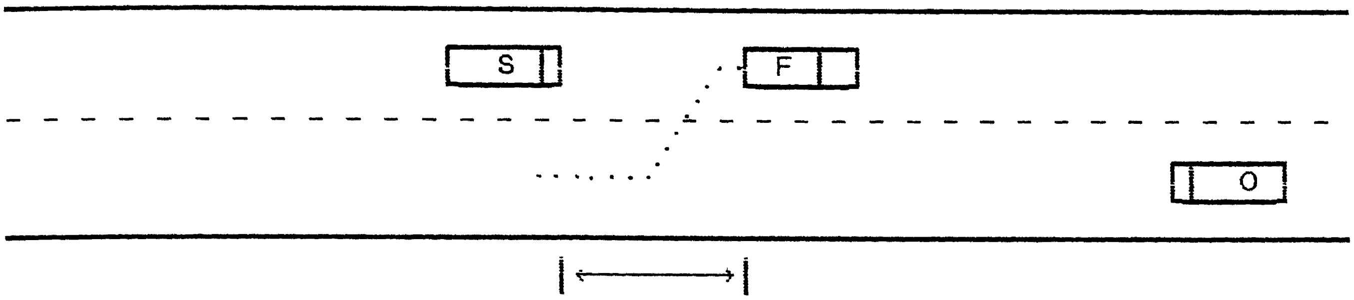
Position at time t_3

Overtaking Manoeuvre Starts (Overtaking Vehicle changes Lane)



Position at time t_4

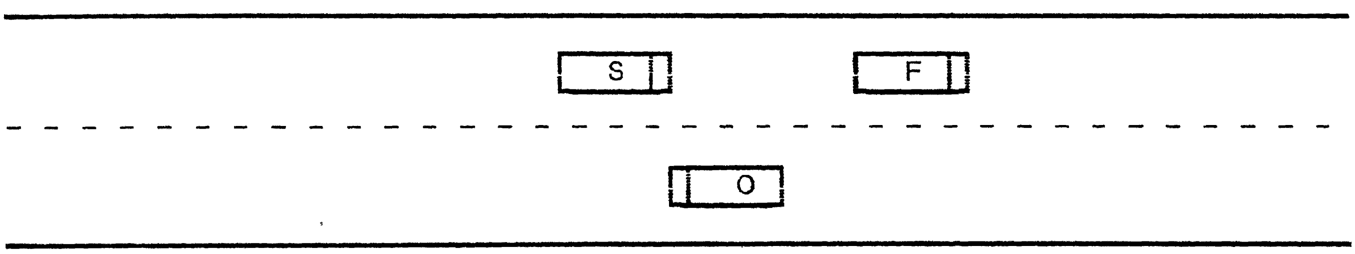
Overtaking Vehicle Levels up with Overtaken Vehicle



(Gap at End of Overtaking)

Position at time t_5

End of Overtaking Manoeuvre (Fast Vehicle returns back to its proper Lane)



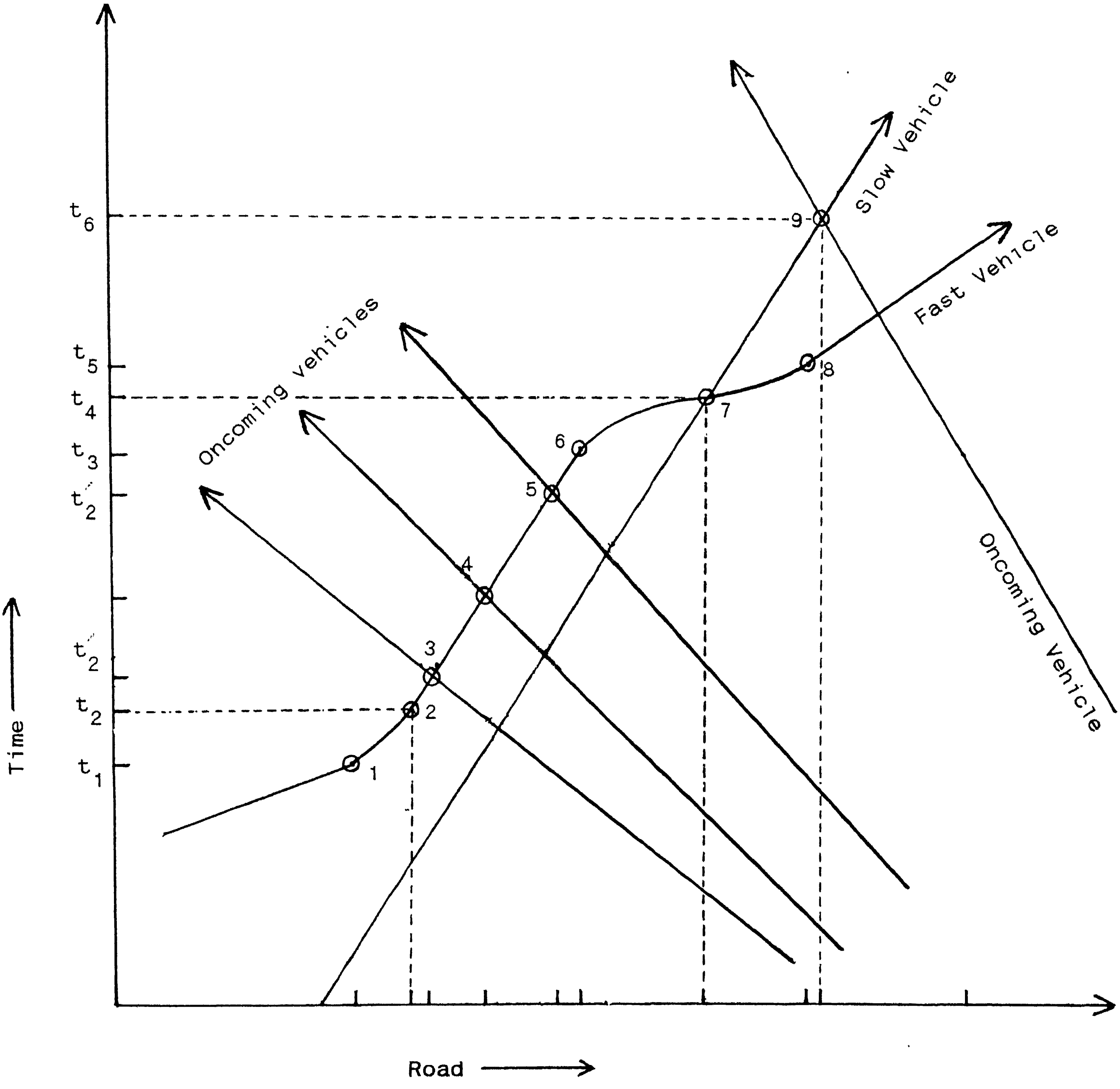
Position at time t_6

Oncoming Vehicle crosses

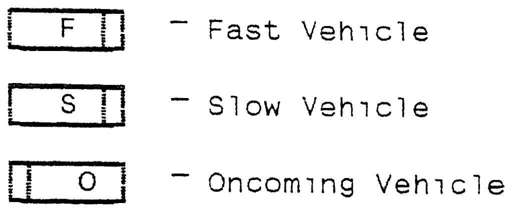
Fig. 4.1 : FLYING OVERTAKING MANOEUVRE

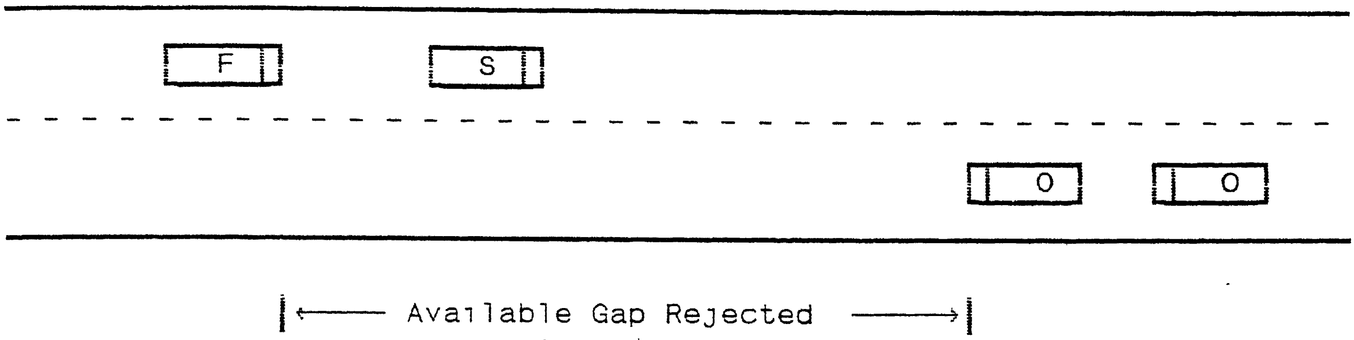
- Decision Point for Flying Overtaking (Opportunity Rejected and Vehicle starts decelerating)
- Vehicle Follows
- Accelerative Overtaking Opportunity (Rejected)
- Accelerative Overtaking Opportunity (Rejected)

5 - Accelerative Overtaking Opportunity (Accepted)
6 - Accelerative Overtaking Starts (Vehicle Accelerates and Changes Lane)
7 - Overtaking Vehicle Levels up with Overtaken Vehicle
8 - Overtaking Ends (Lane Changes)
9 - Oncoming Vehicle Crosses



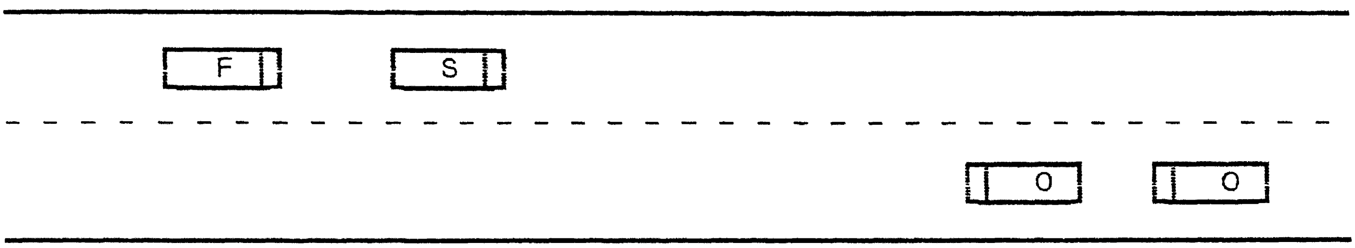
ACCELERATIVE OVERTAKING MANOEUVRE





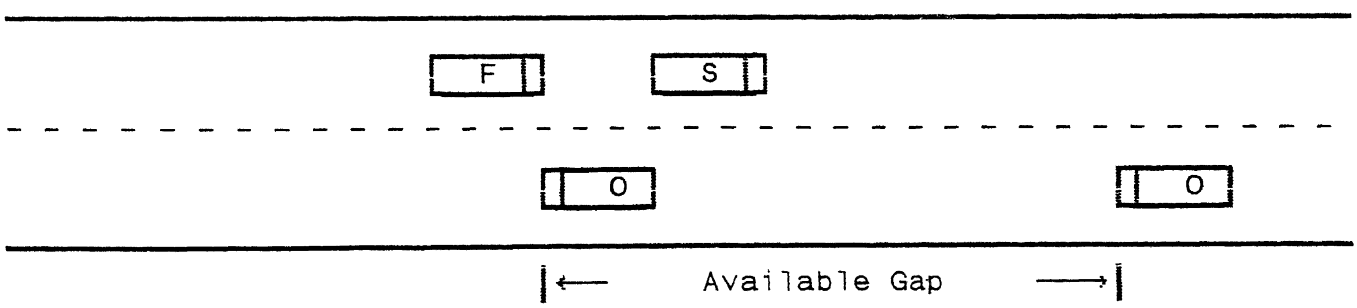
Position at time t_1

Fast Vehicle Catches up (Decision Point for Flying overtaking)



Position at time t_2

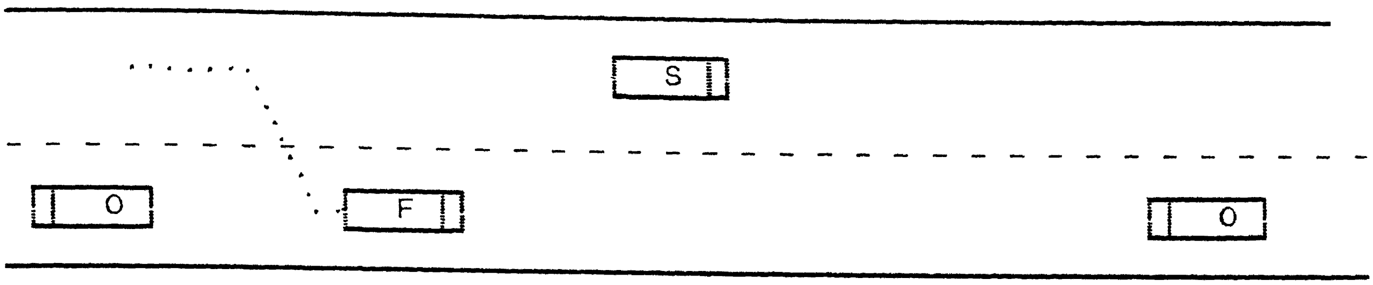
Fast Vehicle follows Slow Vehicle



Position at time t_2'

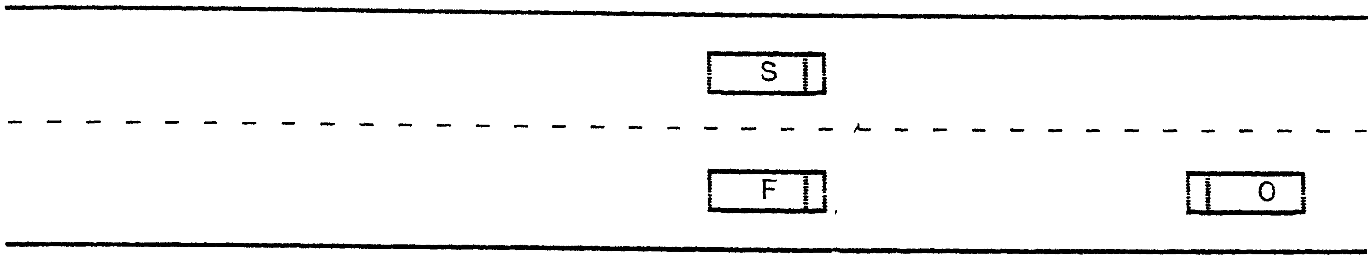
Oncoming Vehicle crosses

(Decesion Point for Accelerative Overtaking)



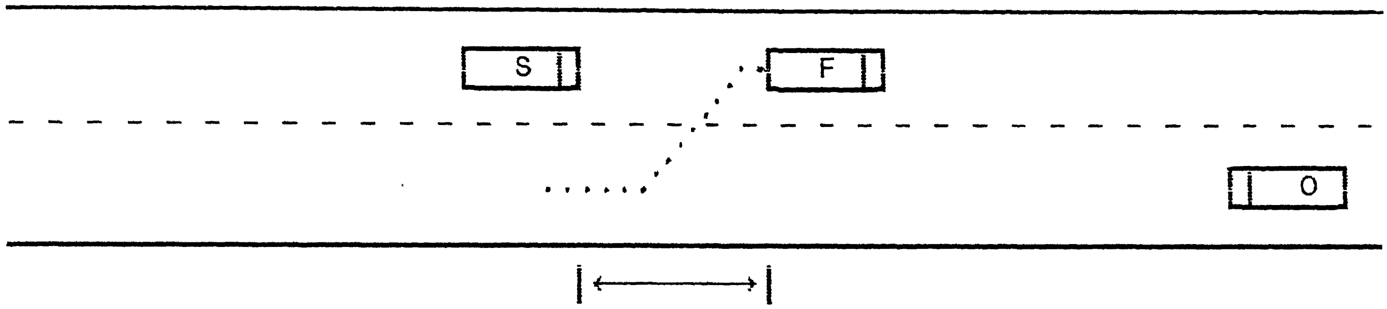
Position at time t_3

Overtaking Manoeuvre starts (Fast Vehicle changes Lane)



Position at time t_4

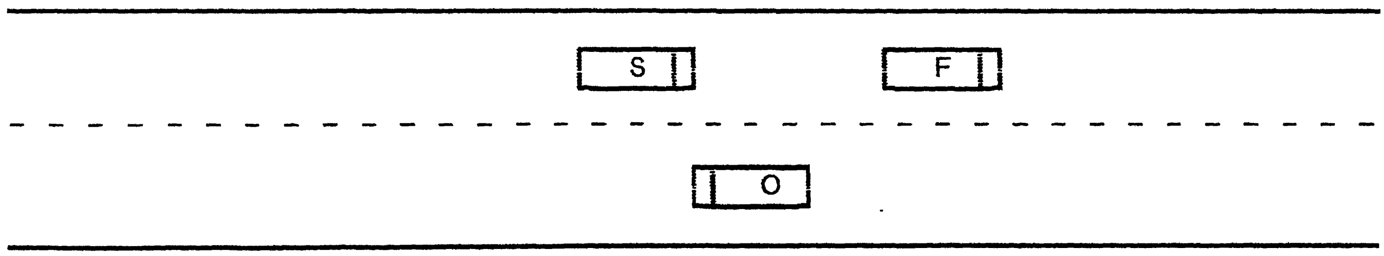
Overtaking Vehicle Levels up with Overtaken Vehicle



(Gap at End of Overtaking)

Position at time t_5

End of Overtaking Manoeuvre (Fast Vehicle returns back to its proper La



Position at time t_6

Oncoming Vehicle crosses

Fig. 4.2 : ACCELERATIVE OVERTAKING MANOEUVRE

4.1.2 ACCELERATIVE OVERTAKING

When the opportunity for the flying overtaking is rejected at time t_1, the vehicle decelerates to the speed of the vehicle ahead and follows. An opportunity of an accelerative overtaking arises when oncoming vehicle crosses the fast vehicle. At this instant (time t_2) the decision is taken about the acceptance or rejection of the opportunity. This decision depends upon the gap between the oncoming obstruction and following vehicle. A following vehicle may reject a number of accelerative overtaking opportunities before it accepts one. The time t_3 is the instant when overtaking starts and the vehicle desiring to overtake changing its lane and accelerates. At time t_4, the overtaking and overtaken vehicles are leveled up. At time t_5, the overtaking is said to be completed when the overtaking vehicle returns back to its proper lane. The crossing of the oncoming obstruction is shown at time t_6.

On the basis of the various aspects explained above the following events of interest are recorded:

- (i) The decision point for flying overtaking.
- (ii) The event when oncoming vehicle (sight limitation point) crosses as this represents the decision point for an accelerative opportunity.
- (iii) The event when an overtaking manoeuvre starts.
- (iv) The event when overtaking vehicle levels up with the overtaken vehicle.
- (v) The event at the end of the overtaking manoeuvre.
- (vi) The event for crossing of the oncoming obstruction as this represents the gap available for the overtaking manoeuvre.

4.2 DESIGN OF DATA RECORDING PROFORMA

In the light of the various events identified for the overtaking manoeuvre, a proforma needs to be prepared for recording the primary data from the video tapes. The transcription of data from overtaking operation to proforma should be easy and effective. A pilot run of a video tape is made to fully understand the recorded data.Based on this experience a proforma (presented in Table 4.1) is designed for primary recording of video data. It may be noted that the proforma is comprehensive enough to record all events of interest with ease. The proforma is designed in such a manner that there is little scope for missing any event. This aspect is very important because any missed or improperly recorded event is likely to cause problems.

The proforma attempts to record the following type of information:

(i) The general characteristic of the overtaking manoeuvre.

- Type of overtaking vehicle.
- Type of overtaken vehicle.
- Type of overtaking (flying/accelerative)

(ii) Data when vehicle desires to perform flying overtaking (vehicle catches up).

- Time at catch up point
- Speed of test vehicle at catch up point
- Position of test vehicle
- Image size of overtaking vehicle at catch up point

(iii) Data when oncoming vehicle crosses the test vehicle

- Type of oncoming vehicle
- Time when oncoming vehicle crossing the test vehicle
- Relative speed of oncoming vehicle
- Speed of test vehicle at point of crossing
- Position of test vehicle at point of crossing

(iv) Data when overtaking manoeuvre starts

- Time at start of overtaking manoeuvre
- Speed of test vehicle at start of overtaking
- Position of test vehicle at start of overtaking
- Image size of overtaking vehicle at start of overtaking

(v) Data when overtaking vehicle levels up with vehicle being overtaken

- Time at level up point
- Speed of test vehicle at level up point
- Position of test vehicle at level up point

(vi) Data when overtaking manoeuvre ends

- Time at end of overtaking manoeuvre
- Relative speed of overtaking vehicle at the end of overtaking manoeuvre
- Speed of test vehicle at end of overtaking
- Position of test vehicle at end of overtaking
- Image size of overtaking vehicle

(vii) Data when oncoming vehicle crosses the test vehicle after overtaking manoeuvre

- Type of oncoming vehicle
- Time at crossing of oncoming vehicle
- Relative speed of oncoming vehicle
- Speed of test vehicle at point of crossing
- Position of test vehicle at point of crossing

TABLE 4.1 : PROFORMA FOR DATA REDUCTION

Name of the road:
Type of terrain :
Type of shoulder:

Type of road :
Date of recording:
Monitor size for coding :

GENERAL CHARACTERISTICS				FAST VEHICLE CATCHES UP				REJECTED OVERTAKING OPPORTUNITY					START OF OVERTAKING				VEHICLES LEVEL UP			END OF OVERTAKING					MEET ONCOMING OBSTRUCTION				
	Type of vehicle		Overtaking type	At catchup point					Oncoming obstructions																				
S No.	Overtaking	Overtaken	Fly... Acc.	Time	Speed of test vehicle	Position of test vehicle	Image size	Type of obstruction	Time	Relative speed of oncoming vehicle	Speed of test vehicle	Position of test vehicle	Time	Speed of test vehicle	Position of test vehicle	Image size	Time	Speed of test vehicle	Position of test vehicle	Time	Relative speed of oncoming vehicle	Speed of test vehicle	Position of test vehicle	Image size for overtaking veh.	Type of obstruction	Time	Relative speed of oncoming vehicle	Speed of test vehicle	Position of test vehicle

The recorded video tapes are analysed in the laboratory to get primary data for each overtaking manoeuvre. The events are recorded on the proforma given earlier in Table 4.1. These primary data are scanned to be used for analysing the characteristics of the overtaking and for estimating the various parameters. Video tape is first run at normal speed to understand the nature of overtaking involved and is played back to a point well before the catching up of the fast vehicle. The tape is now run at slow speed to identify various events of interest. At these events the tape is stopped and observations are recorded. The information recorded at an instant are the transcribed form of the digital information played (time, speed, position of test vehicle) and the image size of the surrounding vehicles as displayed on the monitor.

The recording of the data from the video tape is much time consuming and tiring. The time taken to analyse a video tape depends upon the road and traffic flow characteristics like road width, traffic volume, etc.. Heavy traffic volume has usually large number of interesting events. The continuous running of the tape for recording the data could not be done for more than 4 hours because it causes heavy strain on the eyes.

The analysis of a video cassette took 3 to 4 days on an average, i.e., about 15 to 20 working hours. The analysis is done for 43 video tapes. The details of roads on which the video recording has been done, are presented in the Table 3.1.

The information on the recorded proforma are transferred to a data file that is analysed on the computer. Each of the proforma is visually checked for errors before retrieving the data. Data entry is done in a manner such that each type of events is recorded in a separate line. The coding of the information about certain text like type of overtaking is also required to facilitate the further analysis. An example of the data sheet is given in the Table 4.2. The first value in each line represents the code of event recorded on that line, the codes which are used in the data file are given in the Table 4.3.

The information of 43 video cassettes are first listed separately for each cassette. After testing, the data files are merged in two sets, one for plain terrain and the other for rolling terrain.

4.4 VALIDATION OF PRIMARY DATA

The coded information of the video records resulted in 12391 events encountered (7576 for plain and 4815 for rolling terrain). Each of these data types has 7 to 8 records depending upon the type of data information. The entry of such large data has to be very carefully handled to avoid likely errors and inconsistencies. Visual checks were first made to identify errors and inconsistencies. This visual procedure may not be able to handle such large data accurately.

Therefore, a computer program is developed to locate various errors and inconsistencies. This program (TESTING) goes through all the records and locates the following types of errors:

(i) The arrangement of different data information types is in order.

TABLE 4.2 PRIMARY DATA - A SAMPLE

```
99999 twomnh1.28 Sonipat Panipat Karnal (G T Road) date:= 12-4-92 No.- 28
0 1 0 1
1 9 53 151 57 179 2.5
2 8 9 53 185 60 55 229
2 8 9 53 193 52 55 241
2 1 9 53 205 53 55 258
2 8 9 53 211 51 55 266
2 5 9 53 247 52 55 318
2 7 9 53 322 46 44 415
2 1 9 53 330 46 44 425
2 8 9 53 365 49 47 470
3 9 53 380 44 491 9.0
4 9 53 420 45 546
5 9 53 498 50 54 661 4.0
6 7 9 54 061 40 57 908
0 4 0 1
1 9 56 520 46 352 7.5
2 8 9 56 582 54 41 427
2 7 9 57 110 44 46 577
2 2 9 57 226 43 46 713
3  9 57 233 46 721 28.0
4 9 57 247 45 737
5 9 57 446 14 45 969 8.0
6 99
0 0 7 0
3 9 57 531 56 084 10.0
4 9 57 574 57 151
5 9 58 075 60 56 313 9.0
6 8 9 58 085 86 56 330
0 1 0 1
1 9 58 063 56 295 16.0
2 8 9 58 084 86 54 328
2 8 9 58 109 56 54 367
2 2 9 58 115 60 54 376
2 2 9 58 134 58 57 405
3 9 58 140 57 414 18.0
4 9 58 158 57 444
5  9 58 274 50 55 626 2.5
6 99
0 2 0 1
1 9 58 379 55 788 4.0
2 7 9 58 427 62 55 862
2 7 9 58 434 60 56 873
2 1 9 58 443 57 54 886
2 8 9 58 483 62 55 947
2 7 9 58 562 60 57 1070
2 1 9 58 574 60 56 1089
3 9 58 586 58 1108 14.0
4 9 59 004 57 1136
5 9 59 084 40 56 1262 4.5
6 8 9 59 109 49 56 1300
0 6 0 0
3 9 59 011 56 148 10.5
4 9 59 031 56 187
5 9 59 115 57 56 309 5.5
6 8 9 59 109 49 56 300
```

TABLE 4.3 : CODING FOR DATA FILE

(i) Code for Each Data Type

99999	-	Start of new video Data File
0	-	Start of a new overtaking operation
1	-	Fast vehicle catches up
2	-	Oncoming vehicle crosses the test vehicle
3	-	Overtaking manoeuvre starts
4	-	Overtaking vehicle levels up with vehicle being overtaken
5	-	Overtaking manoeuvre ends
6	-	Oncoming vehicle crosses test vehicle
99	-	When there is no oncoming vehicle

(ii) Codes For Type Of Overtaking

0	-	Flying Overtaking
1	-	Accelerative Overtaking

(iii) Codes For Type Of Vehicles

0	-	Test Vehicle (Maruti Van)
1	-	Maruti Car
2	-	Fiat Car
3	-	Auto rickshaw
4	-	Ambassador Car
5	-	Jeep
6	-	L.C.V.(Light Commercial Vehicle)
7	-	Truck
8	-	Bus
9	-	Tractor
10	-	Horse Cart
11	-	Bullock Cart

(ii) A particular information type is either missing or repeated.

(iii) The number of records in an information type are the same as required.

(iv) There is no inconsistency in the time record, that is, the time of the following event is higher than the previous event in the overtaking manoeuvre.

(v) Any inconsistency in the position record. For example, when the time of occurrence of any event is higher than early event then the position value of the test vehicle should also be higher.

(vi) Any inconsistency in the joint record of time and position.

(vii) The number of information type that follow are consistent with the type of overtaking (flying/accelerative) identified in the first information type of overtaking characteristics.

(viii) The vehicle codes are within the specified limits.

(ix) All records are of integer value except the image size which has a real value.

Besides the above inconsistencies the program also determines the values of various parameters. These parameter values are compared with the most likely lower and upper limits. If the value does not lie in

the range, the message is printed. This may not necessarily be an error because some outliers may be present. This information is checked with noted records on the proforma and corrected in case of any discrepancy.

This testing of the data is of great help in locating the errors and inconsistencies. The testing is done separately for each file of a video cassette. After complete validation of the data, the files are merged to make two groups one for plain terrain and other for rolling terrain. The structure of the Data Extraction Program System is represented in Fig.4.3.

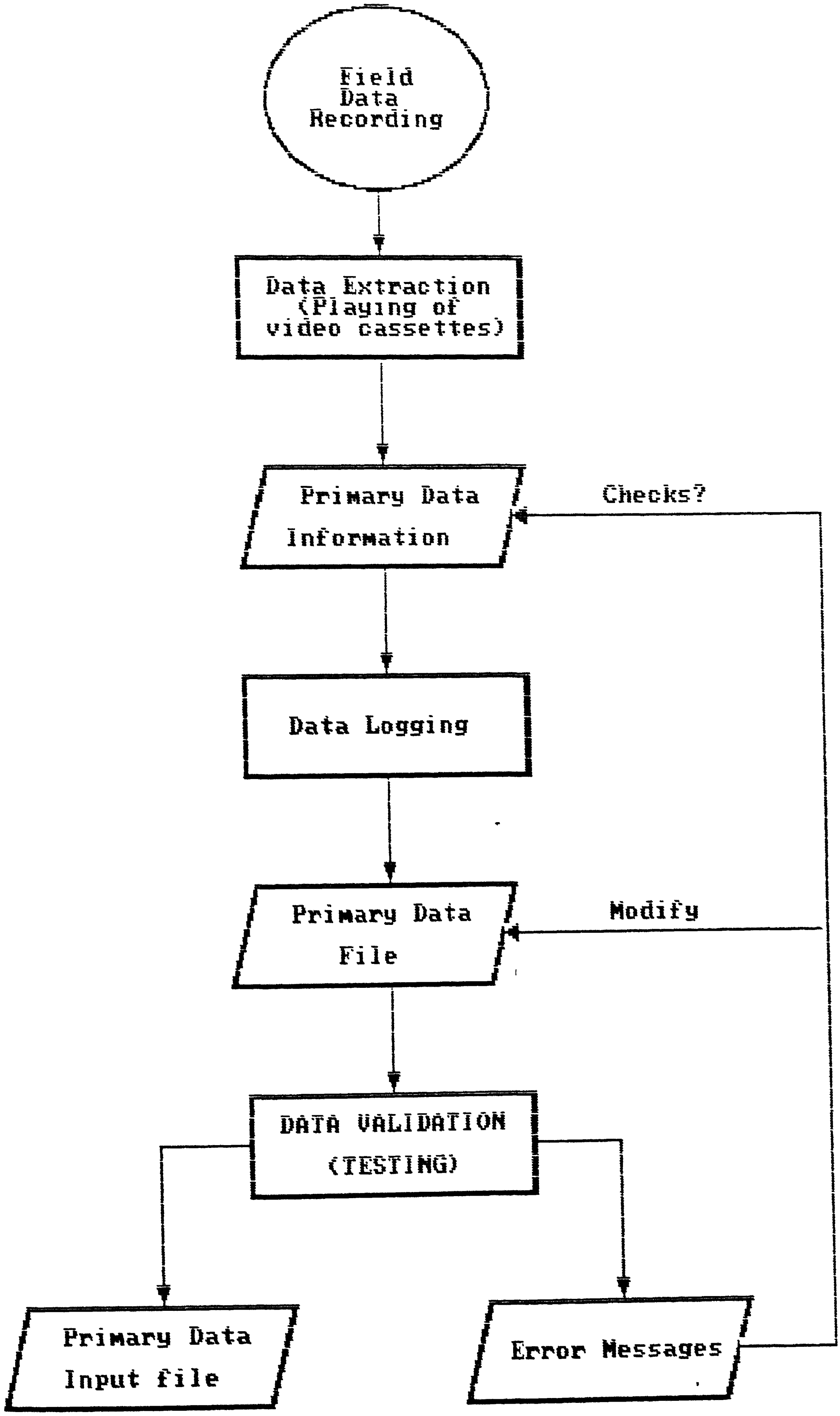


Fig 4.3 : Data Extraction Program

5. ANALYSIS OF OVERTAKING MANOEUVRE

5.1 INTRODUCTION

The primary data, as validated in section 4.4, could be used to calculate the value of the derived parameters which quantify the overtaking manoeuvre. The derived parameters of primary interest in this study are:

(i) Oncoming gap for rejected opportunities.
(ii) Oncoming gap for accepted opportunities.
(iii) Gap for catch-up position.
(iv) Gap at start of overtaking.
(v) Gap from start to level-up point.
(vi) Gap from level-up to end of overtaking.
(vii) Gap from start to end of overtaking.
(viii) Gap between end of overtaking and oncoming vehicle/sight obstruction.

There are few other parameters also which could be estimated from the observed data. This study is however restricted to only eight parameters listed above.

Most of the parameters involve estimation of the gaps in the overtaking manoeuvre. These gaps may be defined both in terms of time and distance. Time gaps are more accurately determined from observed data. Distance gap requires estimation of the distance of other vehicle from test vehicle like distance to overtaking, oncoming vehicle, etc. The computations of the distance gaps involve the speed of the oncoming vehicle. It was noticed during data extraction phase that the radar speedometer, which records the relative speed of oncoming vehicle, does not function properly at times and records erratic values.

It may be argued that the speed of the oncoming vehicle could be estimated from the image size of oncoming vehicle taken at close intervals. The image size of oncoming vehicle is so small when it is in view that the recording error in the image size produces significant difference in the estimated values. For example a truck which is 150 meters away produces an image size of 1.0 cm., which is bound to have an error of 2-3 mm. in recordings. Based on the above observations, it is true that the gaps computed in terms of time are more accurate than those computed in terms of distance. Inspite of these deficiencies the gaps are calculated both in terms of time and distance. The values of all the derived parameters are analysed separately for time gap and space gap measurements

The analysis of the overtaking manoeuvre is carried out in following ways:

(a) Study the nature of different derived parameters. This analysis helps to identify the general nature and to plan for other type of analysis.

(b) Analysis of the statistics for the derived parameters. This is planned at various disaggregated levels.

(c) Study of rejected/accepted opportunities and to compute the probability of gap acceptance.

5.2 EXPERIMENTAL DESIGN FOR ANALYSIS

The overtaking process is affected by road, driver, vehicle and traffic characteristic. The quantification of the derived parameter needs to be studied under different levels. One has to

very carefully identify the levels of various parameters which could be used for analysis. There should also be sufficient number of observation for each level to estimate the characteristic of the parameters. The experimental design for analysis of data as planned in this study is presented in the Table 5.1.

The Primary Data File obtained after data validation is given as input to compute the details of each overtaking manoeuvre. These details of individual manoeuvre are subjected to different types of analysis as listed above.

The analysis involves the development of a number of computer program. The emphasis is also laid on the graphical display of the statistics for different parameters. The complete structure of the program development and their interactions are illustrated in Fig. 5.1.

5.3 COMPUTATION OF INDIVIDUAL OVERTAKING DETAILS

The various parameters that help to quantify the different aspects of an overtaking manoeuvre are computed separately for plain and rolling terrain data. The total number of rejected/accepted overtaking opportunities are presented in Table 5.2.

It is seen that the sample size of the overtaking manoeuvre is sufficiently large for statistical analysis. The total number of flying and accelerative overtaking manoeuvres for plain terrain are very close to each other, being 393 and 371 respectively. But for rolling terrain, the number of flying overtaking are much

TABLE 5.1 : EXPERIMENTAL DESIGN FOR ANALYSIS

(i) Road Characteristic
- (a) Plain Terrain
- (b) Rolling Terrain

(ii) Nature of Overtaking
- (a) Flying Overtaking
- (b) Accelerative Overtaking

(iii) Type of Overtaking Vehicles
- (a) Maruti
- (b) Other Cars
- (c) L.C.V.
- (d) Truck
- (e) Bus
- (f) All Vehicles

(iv) Type of Overtaken Vehicle
- (a) Test Vehicle (Maruti Van)

TABLE 5.2 : SAMPLE SIZE FOR OVERTAKING MANOEUVRES

		Flying Overtaking		Accelerative Overtaking	
		Rejected	Accepted	Rejected	Accepted
Test Vehicle Overtaken by Other Vehicles	Plain	371	393	814	371
	Rolling	150	319	152	150
Overtaking by Test Vehicle	Plain	128	203	264	128
	Rolling	123	189	194	123
	Total	772	1104	1424	772

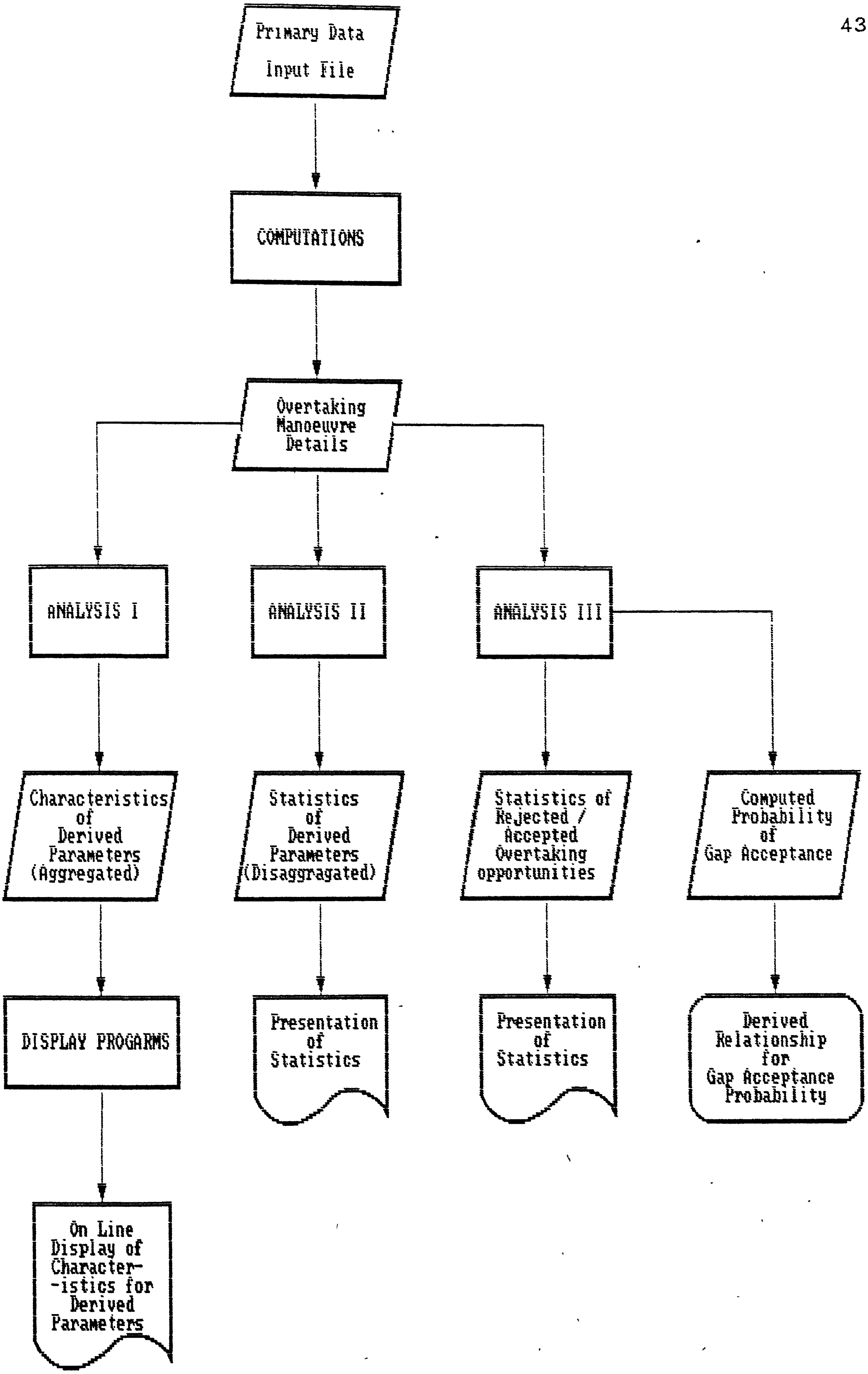


Fig. 5.1 : Program Structure for Data Analysis

larger than accelerative ones,being 319 and 150 respectively. The flying overtaking manoeuvres are more in rolling terrain as these roads generally have lower traffic volume than plain terrain. When traffic volume is low, the available gaps are larger and more flying opportunities are accepted by overtaking vehicle.

The variables involved in describing the details of different types of overtaking manoeuvre and their relationships for computation are presented in Table 5.3 to 5.6.

The program COMPUTATIONS does the necessary calculation for the overtaking data recorded in the Primary Data Input File. The nature of overtaking (flying or accelerative), overtaking by test vehicle or overtaking of test vehicle, are recorded along with all the values of different parameters explaining the components of the manoeuvre. This information is recorded in the file 'Overtaking Manoeuvre Details'. An example of this file is presented in Table 5.7. This file is an input to the different analysis programs (Analysis I ,II and III)

TABLE 5.3 : PRIMARY DATA INPUT

Data Type 0 - Start of a new Overtaking Operation

vehfast	-	Type of the fast vehicle desiring to overtake 0 for test vehicle, 1 - 11 for other vehicle types
vehslow	-	Type of the slower vehicle to be overtaken 0 for test vehicle, 1 - 11 for other vehicle types
typeovtake	-	Type of overtaking executed 0 for Flying Overtaking 1 for Accelerative overtaking)

Data Type 1 - Fast Vehicle catches up (Decision point for Flying Overtaking)

catuptime	-	Time at catch up point in seconds
catuppos	-	Position of Test Vehicle in meters
catupspeed	-	Speed of Test Vehicle at catchup point in Kmph
catupspacing	-	Spacing between the Test Vehicle and catching up vehicle or Spacing between the Test Vehicle and caught up vehicle when Test Vehicle is overtaking

Data Type 2 - Oncoming Vehicle crosses the Test Vehicle

vehcrossing	-	Type of vehicle crossing
crosstime	-	Time of crossing in seconds
relspeedcross	-	Relative speed of crossing vehicle in kmph
crosspeed	-	Speed of Test Vehicle at point of crossing
crosspos	-	Position of Test Vehicle at point of crossing in meters

Data Type 3 - Overtaking Manoeuvre Starts (Fast vehicle changes lane)

starttime	-	Time at start of overtaking manoeuvre in seconds
startspeed	-	Speed of Test Vehicle at start of overtaking in kmph
startpos	-	Position of Test Vehicle at start of overtaking in meters
startspacing	-	Spacing between the overtaking and overtaken vehicles in meters

Table 5.3 - (continued)

Data Type 4 - Overtaking vehicle levels up with vehicle being overtaken

leveltime	- Time at level up point in seconds
levelspeed	- Speed of Test Vehicle at level up point in kmph
levelpos	- Position of Test Vehicle at level up point in meters

Data Type 5 - Overtaking manoeuvre ends (Overtaking vehicle returns to its proper lane)

endtime	- Time at end of overtaking manoeuvre in seconds
relspeedend	- Relative speed of overtaking vehicle at end of overtaking manoeuvre in kmph
endspeed	- Speed of Test Vehicle at end of overtaking manoeuvre in kmph
endpos	- Position of Test Vehicle at end of overtaking manoeuvre in meters
endspacing	- Spacing between overtaking and overtaken vehicle at end of overtaking manoeuvre in meters

Data Type 6 - Oncoming vehicle crosses Test Vehicle

vehcrossing	- Type of oncoming vehicle
crosstime	- Time at crossing of oncoming vehicle in seconds
relspeedcross	- Relative speed of oncoming vehicle in kmph
crossspeed	- Speed of Test Vehicle at point of crossing in kmph
crosspos	- Position of Test Vehicle at point of crossing in meters

TABLE 5.4 : COMPUTATIONS WHEN FLYING OPPORTUNITY IS REJECTED

Oncominggap	-	Space gap between vehicle desiring to overtake and oncoming vehicle
Oncominggap	=	(crosspos-lookforpos)+(crosstime-lookfortime)* 0.2778 * (relspeedcross)+catupspacing + 6.0;
Oncomingtimegap	-	Time gap between vehicle desiring to overtake and oncoming vehicle
Oncomingtimegap	=	crosstime - lookfortime;
lookfortime	-	Time at which an opportunity arises (oncoming vehicle crosses)
lookfortime	=	crosstime;
lookforpos	-	Position of Test Vehicle when an opportunity arises (oncoming vehicle crosses)
lookforpos	=	crosspos;

TABLE 5.5 : COMPUTATIONS WHEN ACCELERATIVE OPPORTUNITY IS REJECTED

Oncominggap - Space gap between vehicle desiring to overtake and oncoming vehicle

```
Oncominggap:=(crosspos-lookforpos)+(crosstime-lookfortime)*
              0.2778 * (relspeedcross )+catupspacing + 6.0;
```

Oncomingtimegap - Time gap between vehicle desiring to overtake and oncoming vehicle

```
Oncomingtimegap:= crosstime - lookfortime;
```

lookfortime - Time at which an opportunity arises (oncoming vehicle crosses)

```
lookfortime:=crosstime;
```

lookforpos - Position of Test Vehicle when an opportunity arises (oncoming vehicle crosses)

```
lookforpos:=crosspos;
```

TABLE 5.6 : COMPUTATIONS WHEN OVERTAKING IS EXECUTED

accgaptime - Available time gap accepted for acceleratve overtaking

When Test Vehicle is overtaking
accgaptime:= crosstime- starttime;

When Test Vehicle is being overtaken
accgaptime:= crosstime- starttime+
0.5(startspacing/0.2778*startspeed);

accgaplength - Available space gap accepted for acceleratve overtaking

accgaplength:= crosspos-startpos+startspacing+ 0.2778 *
(crosstime-starttime)*(relspeedcross)+6.0;

levelgaptime - Time gap between start of overtaking and level up
levelgaptime:= leveltime-starttime;

levellength - Space gap between start of overtaking and level up
levellength:= levelpos-startpos+ startspacing +6.0;

endgaptime - Time gap between level up and end of overtaking
endgaptime:=endtime-leveltime;

endspacing - Space gap between level up and end of overtaking

ovtaketime - Time gap between start and end of overtaking
ovtaketime:= endtime- starttime;

ovtakelength - Space gap between start and end of overtaking
ovtakelength:= (endpos-startpos) + (endspacing+startspacing);

When Test Vehicle is overtaking :
ovtakelength:= (endpos-startpos) ;

Table 5.6 - (continued)

headwaystart -	Time headway at start of overtaking
headwaystart :=	startspacing/(0.2778*startspeed);
headwaycatchup -	Time headway between slower vehicle and caught up vehicle at catch up point
headwaycatchup:=	catchpspacing/ (0.2778*catchupspeed) ;
safetytime -	Safety time for overtaking (Time gap between end of overtaking and crossing of oncoming vehicle)

safetytime := accgaptime - ovtaketime;

safetylength	Safety length for overtaking (Space gap between end of overtaking and oncoming vehicle)

safetylength:=0.2778*safetytime*relspeedcross;

TABLE 5.7 : OVERTAKING MANOEUVRE DETAILS - A SAMPLE

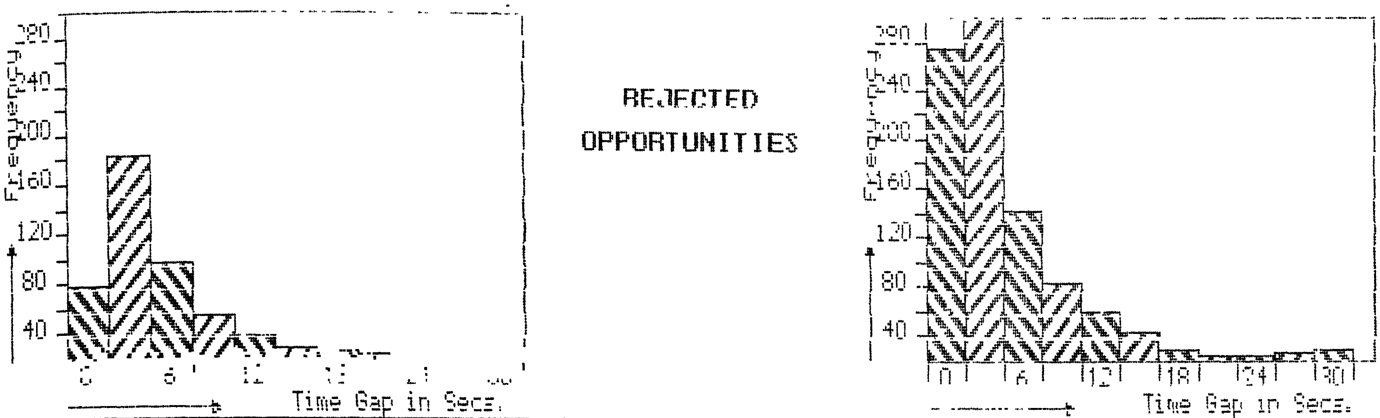
date-7-1-92 (Jaipur-Ajmer)(2L)(no-A-5)

201	Fly Rejection of TV	4	0	7	54	55.0	49	98	221.1	3.9	166.1
211	Acc Rejection of TV	4	0	8	54	55.0	49	98	97.5	0.9	42.5
211	Acc Rejection of TV	4	0	7	54	55.0	51	102	127.4	1.6	72.4
212	Acc Acceptance of TV	4	0	5	46	43.0	14	28	382.0	19.8	339.0
		121.0	6.2	37	55.0	232.0	12.2	177.0	59.1	7.6	4.1
201	Fly Rejection of TV	7	0	7	30	100.0	30	60	184.0	3.3	84.0
211	Acc Rejection of TV	7	0	7	30	100.0	29	58	150.7	1.9	50.7
211	Acc Rejection of TV	7	0	7	30	100.0	27	54	157.0	2.2	57.0
212	Acc Acceptance of TV	7	0	7	26	49.4	23	46	337.5	14.1	288.2
		99.4	6.0	22	58.2	191.6	11.4	133.4	34.5	2.7	-23.7
201	Fly Rejection of TV	7	0	7	23	53.6	23	46	72.6	0.7	18.9
212	Acc Acceptance of TV	7	0	7	24	23.4	21	42	577.7	30.7	554.2
		44.4	2.4	20	49.4	124.8	9.1	75.4	252.2	21.6	202.8
202	Fly Acceptance of TV	7	0	7	32	27.4	29	58	552.6	21.3	525.2
		72.4	4.5	29	49.4	178.7	12.6	129.4	140.3	8.7	91.0
202	Fly Acceptance of TV	7	0	3	26	18.3	27	54	550.8	22.9	532.5
		56.3	4.0	29	58.2	197.4	14.8	139.3	121.6	8.1	63.4
102	Fly Acceptance by TV	0	7	99	63	46.3	45	45	903.7	33.2	857.4
		62.0	3.5	45	49.4	295.0	18.2	245.6	187.7	15.0	138.3
101	Fly Rejection by TV	0	7	7	46	100.0	44	88	69.2	1.6	-30.9
111	Acc Rejection by TV	0	7	7	46	100.0	42	84	74.3	1.9	-25.7
111	Acc Rejection by TV	0	7	8	46	100.0	42	84	62.0	1.5	-38.0
111	Acc Rejection by TV	0	7	7	46	100.0	50	100	785.8	19.0	685.8
111	Acc Rejection by TV	0	7	5	46	100.0	51	102	629.9	15.1	529.9
111	Acc Rejection by TV	0	7	7	46	100.0	50	100	618.5	14.6	518.5
112	Acc Acceptance by TV	0	7	10	59	21.1	53	106	870.5	19.0	849.4
		156.1	8.2	54	23.4	394.0	25.5	370.6	-191.5	-6.5	-215.0
101	Fly Rejection by TV	0	8	10	59	28.7	53	106	95.9	2.0	67.2
112	Acc Acceptance by TV	0	8	7	54	17.7	59	118	1580.6	31.9	1562.9
		102.7	5.5	68	53.6	321.0	19.8	267.4	397.0	12.1	343.3
101	Fly Rejection by TV	0	7	3	36	53.6	33	66	39.0	1.2	-14.7
111	Acc Rejection by TV	0	7	7	36	53.6	31	62	48.3	1.7	-5.4
111	Acc Rejection by TV	0	7	5	36	53.6	30	60	34.4	1.1	-19.3
112	Acc Acceptance by TV	0	7	7	27	17.7	42	84	459.1	13.2	441.4
		39.7	1.8	46	35.0	125.0	11.6	90.0	37.4	1.6	2.4

5.4 NATURE OF DERIVED PARAMETERS (PROGRAM ANALYSIS I)

This analysis aims to have a feel of the distributions of the values of different parameters. The analysis is carried out by aggregating all types of overtaking vehicles. The analysis is done separately for plain and rolling terrains and the overtaking manoeuvres are classified into flying and accelerative overtakings. The program ANALYSIS I determines the frequency distributions for each of the parameters. This information is input for a display program which provides online graphic display of different parameters. Each screen shows the bar chart and cumulative bar chart, separately for flying and accelerative overtaking operations. This program is so structured that the graphic images on the screen can be directly printed on a hard copy. The online graphic displays for plain terrain are shown in Figs. 5.2 to 5.10. All these displays represent time gaps only. A similar set is also obtained for space gap values.

These illustrations show that there is a wide dispersion amongst the values of different parameters. The dispersions are generally left skewed and skewed to right for some of the parameters. The mean and standard deviation values for each parameter are also presented in each illustration. These online graphic displays help to understand the nature of distribution and to plan for further analysis at disaggregated level.



DISTRIBUTION OF REJECTED / ACCEPTED OPPORTUNITIES	FLYING OVERTAKINGS		ACCELERATIVE OVERTAKINGS	
	REJECTED	ACCEPTED	REJECTED	ACCEPTED
NO OF OBSERVATIONS	371	393	814	371
MEAN TIME GAP (SEC)	6.48	25.85	6.57	23.53

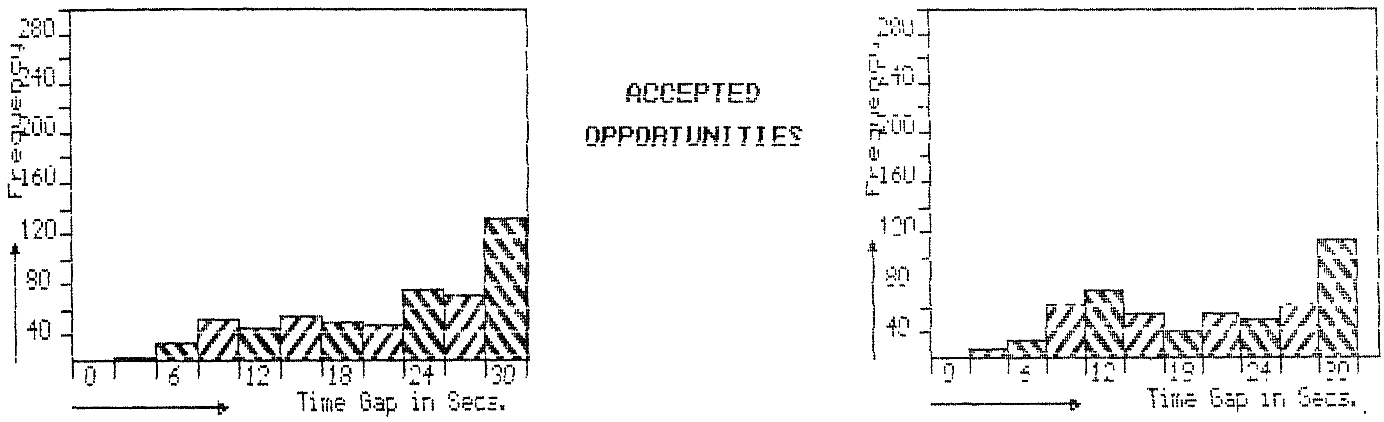
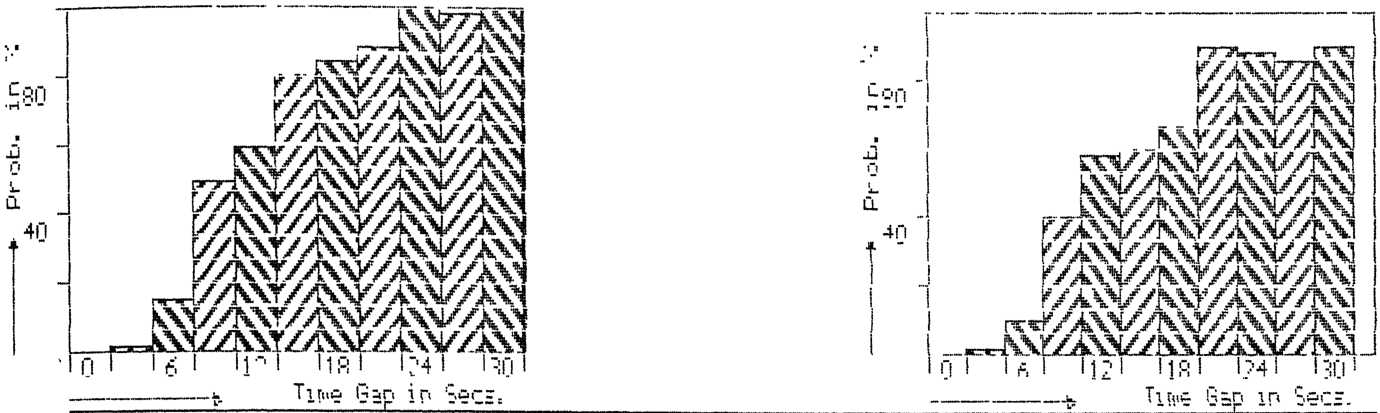


Fig. 5.2 : DISTRIBUTION OF TIME GAPS FOR REJECTED/ACCEPTED OPPORTUNITIES (PLAIN TERRAIN)



PROBABILITY OF GAP ACCEPTANCE	FLYING OVERTAKINGS	ACCELERATIVE OVERTAKINGS
NO OF OBSERVATIONS	393	371

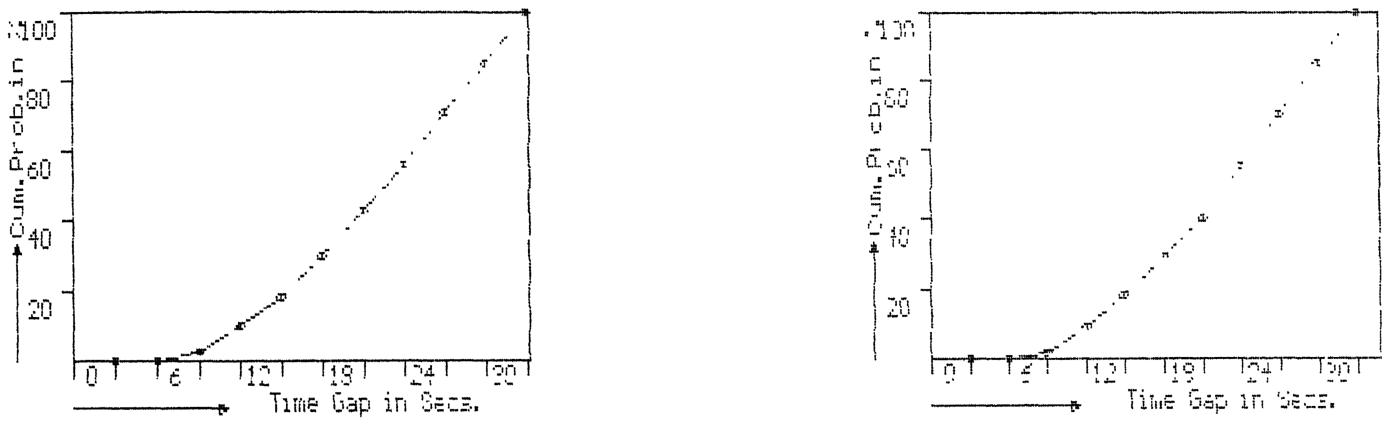
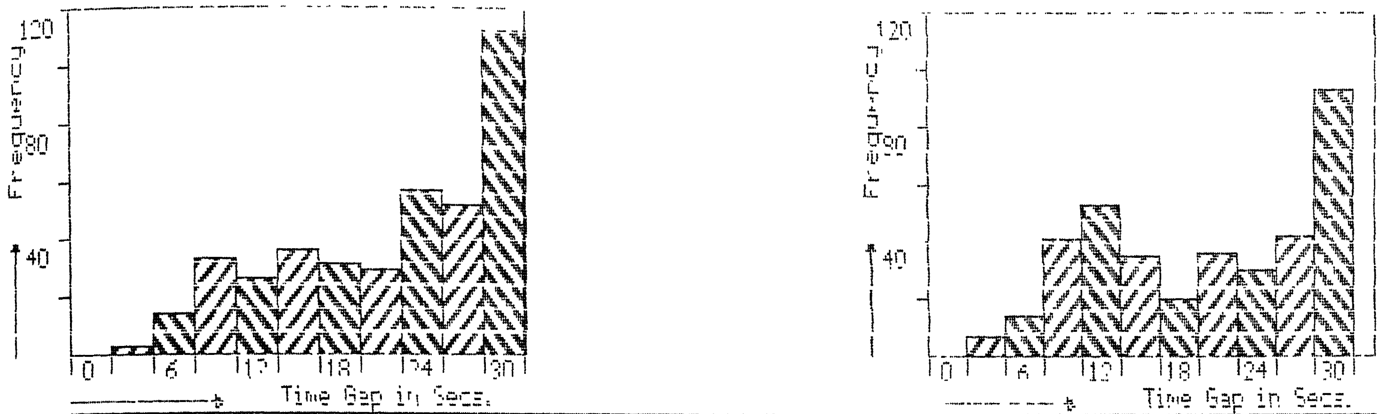


Fig. 5.3 : PROBABILITY OF TIME GAP ACCEPTANCE (PLAIN TERRAIN)



DISTRIBUTION OF ACCEPTED OPPORTUNITIES	FLYING OVERTAKINGS	[illegible] OVERTAKINGS
NO. OF OBSERVATIONS	393	371
MEAN TIME GAP (SEC.)	25 85	23 53
STANDARD DEVIATION	13.05	12.22

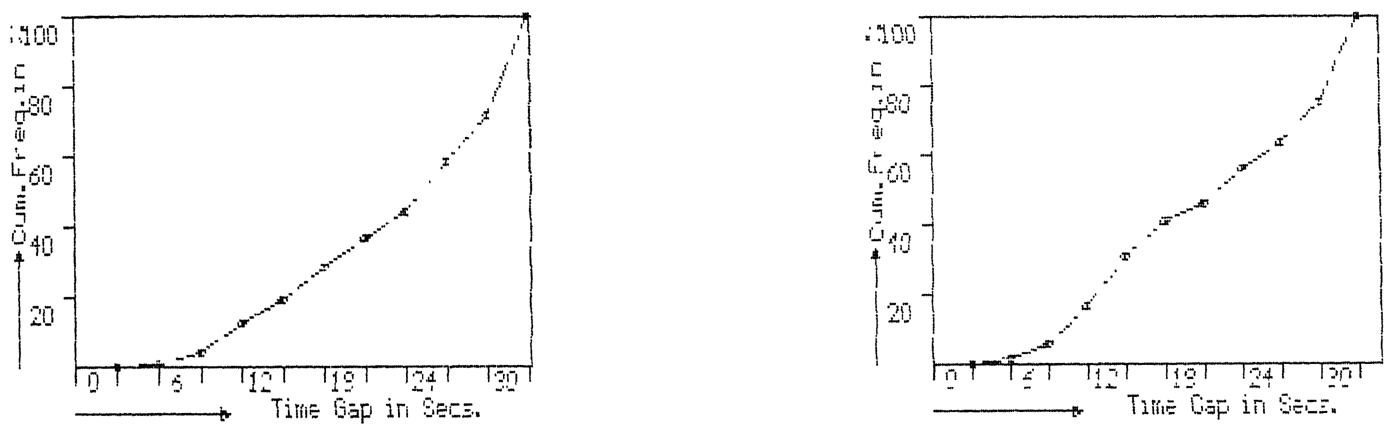
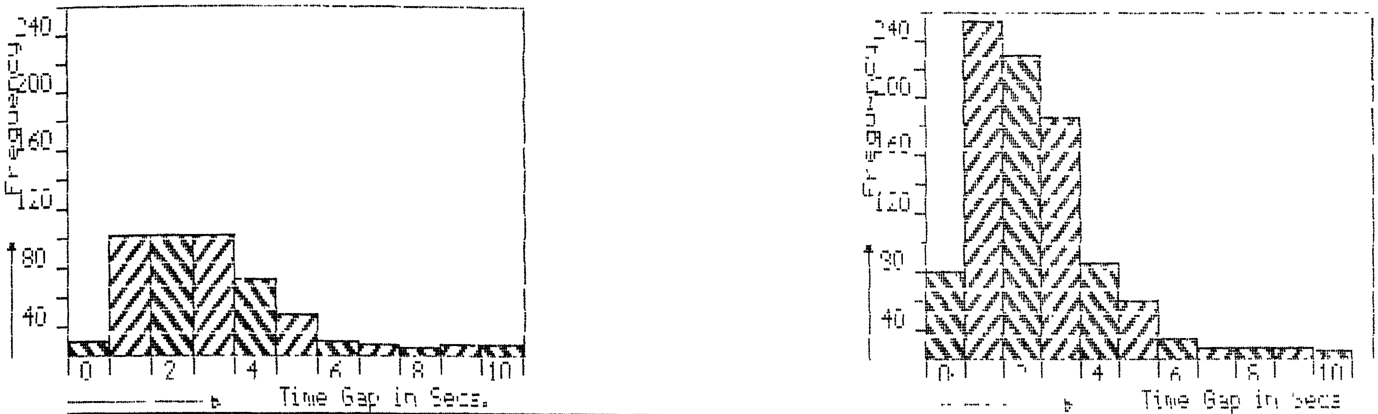


Fig. 5.4 : DISTRIBUTION OF TIME GAP FOR ACCEPTED OPPORTUNITIES (PLAIN TERRAIN)



DISTRIBUTION OF GAPS AT CATCH-UP POINT	FLYING OVERTAKINGS	ACCELERATIVE OVERTAKINGS
NO. OF OBSERVATIONS	371	814
MEAN TIME GAP (SEC.)	3.62	2.94
STANDARD DEVIATION	2.35	1.83

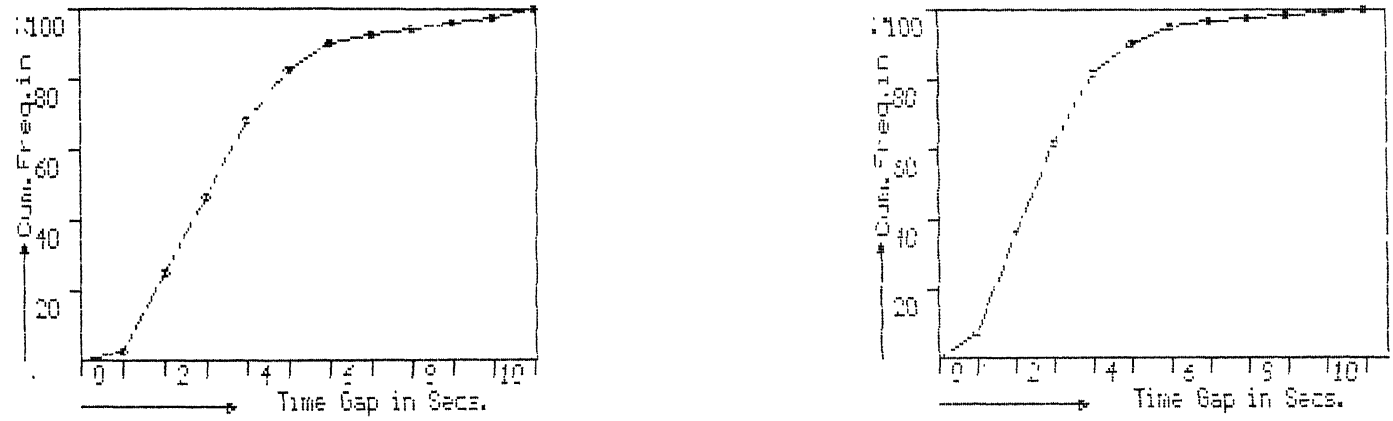
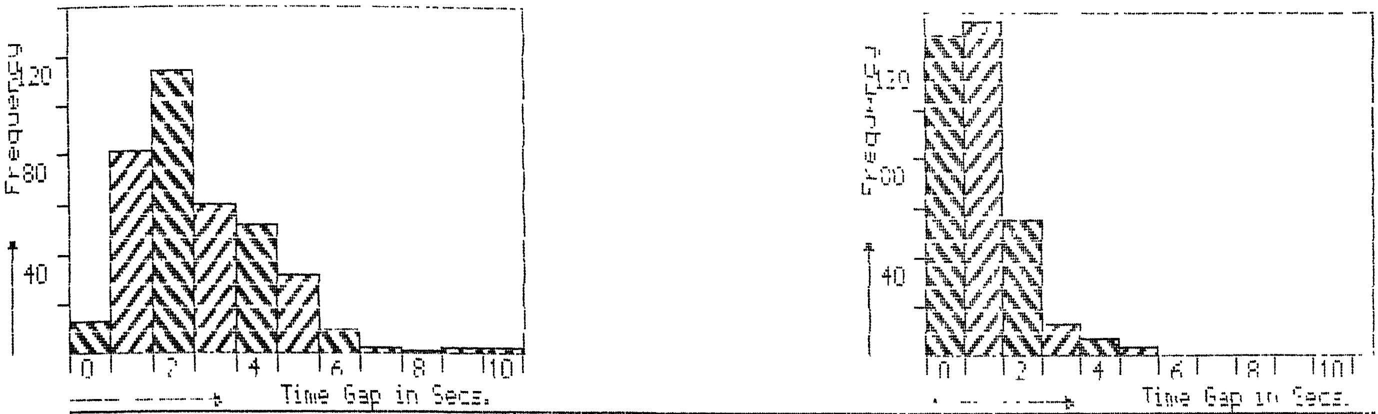


Fig. 5.5 : DISTRIBUTION OF TIME GAPS AT CATCH-UP POINT (PLAIN TERRAIN)



DISTRIBUTION OF GAPS AT START OF OVERTAKING		
	FLYING OVERTAKINGS	ACCELERATIVE OVERTAKINGS
NO OF OBSERVATIONS	393	371
MEAN TIME GAP (SEC)	3.13	1.52
STANDARD DEVIATION	1.84	0.91

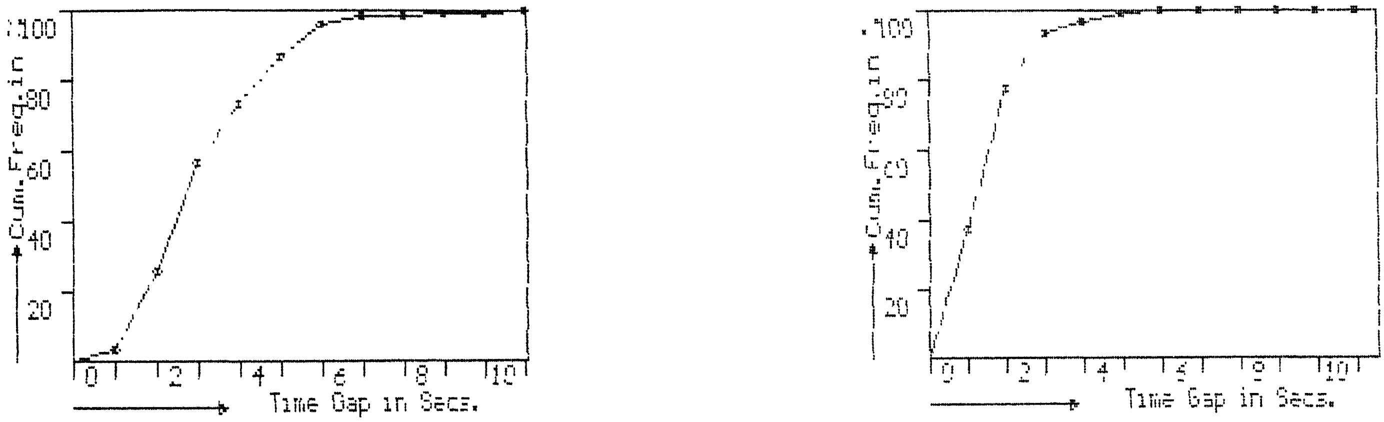
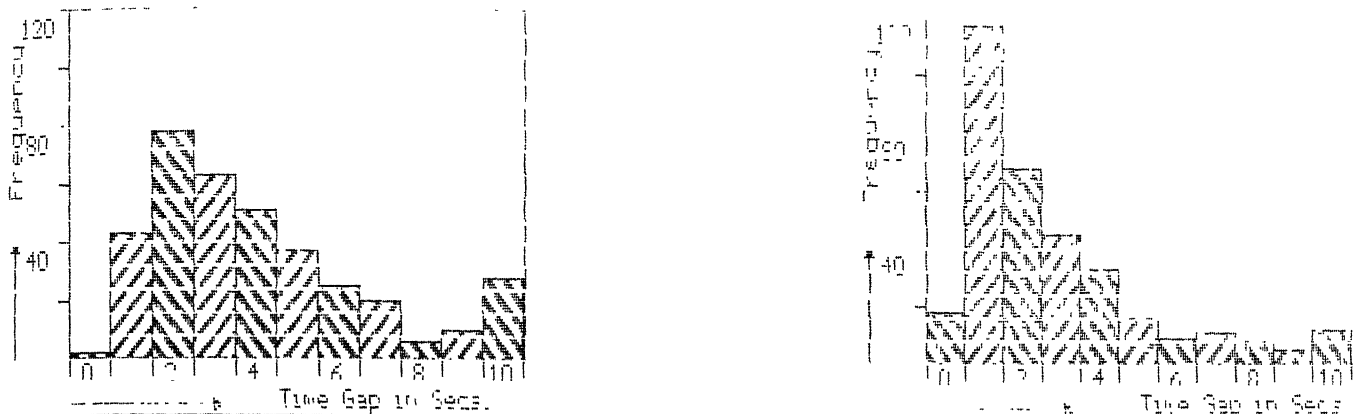


Fig. 5.6 : DISTRIBUTIONS OF TIME GAPS AT START OF OVERTAKING (PLAIN TERRAIN)



DISTRIBUTION OF GAPS FROM START TO LEVEL-UP	FLYING OVERTAKING	[illegible]
NO OF OBSERVATIONS	393	371
MEAN TIME GAP (SEC)	4.95	3.44
STANDARD DEVIATION	3.66	2.77

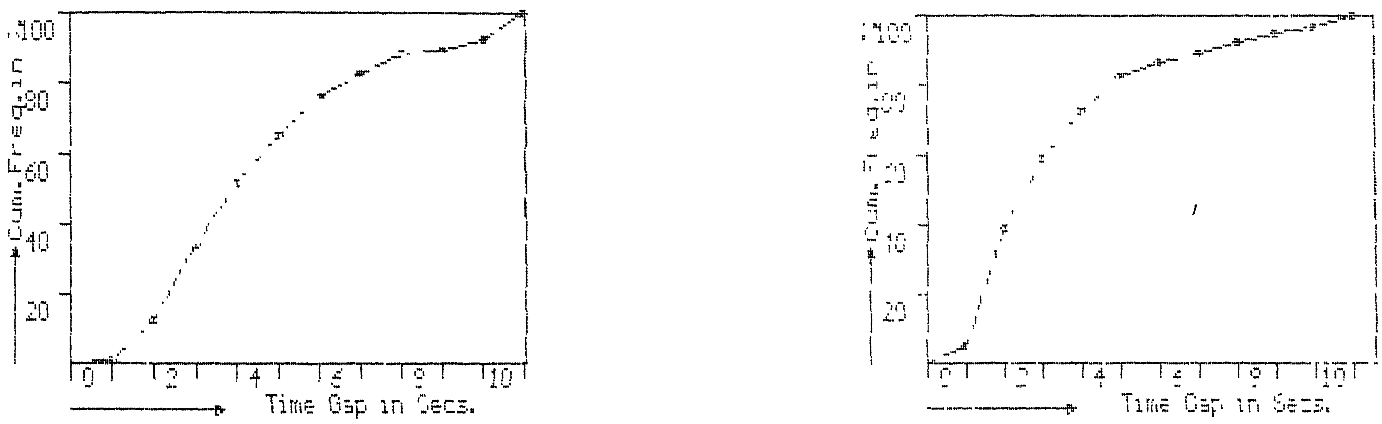
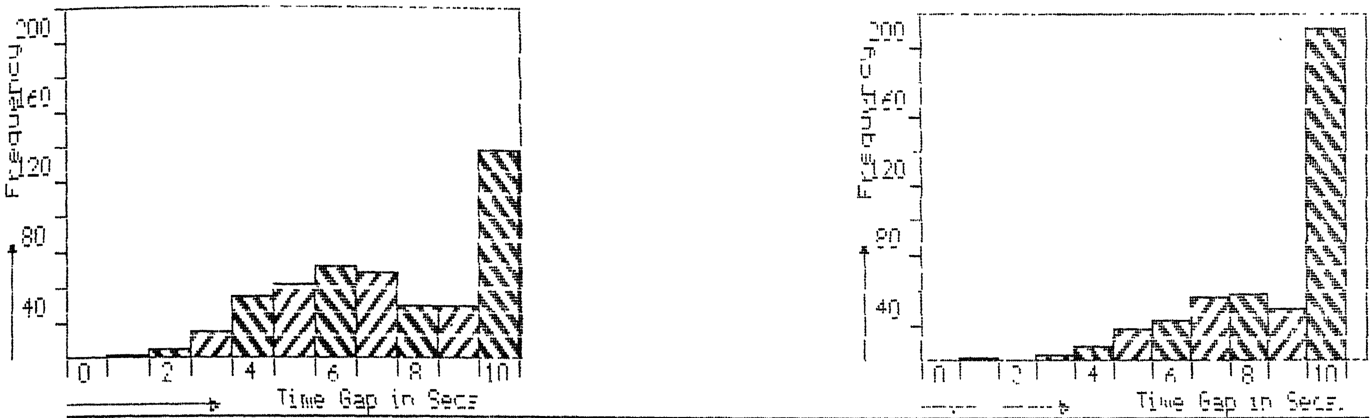


Fig. 5.7 : DISTRIBUTION OF TIME GAPS FROM START TO LEVEL-UP

(PLAIN TERRAIN)



DISTRIBUTION OF GAPS FROM LEVEL-UP TO END OF OVERTAKING		
	FLYING OVERTAKINGS	ACCELERATIVE OVERTAKINGS
NO OF OBSERVATIONS	393	371
MEAN TIME GAP (SEC.)	8.93	11.20
STANDARD DEVIATION	4.41	4.58

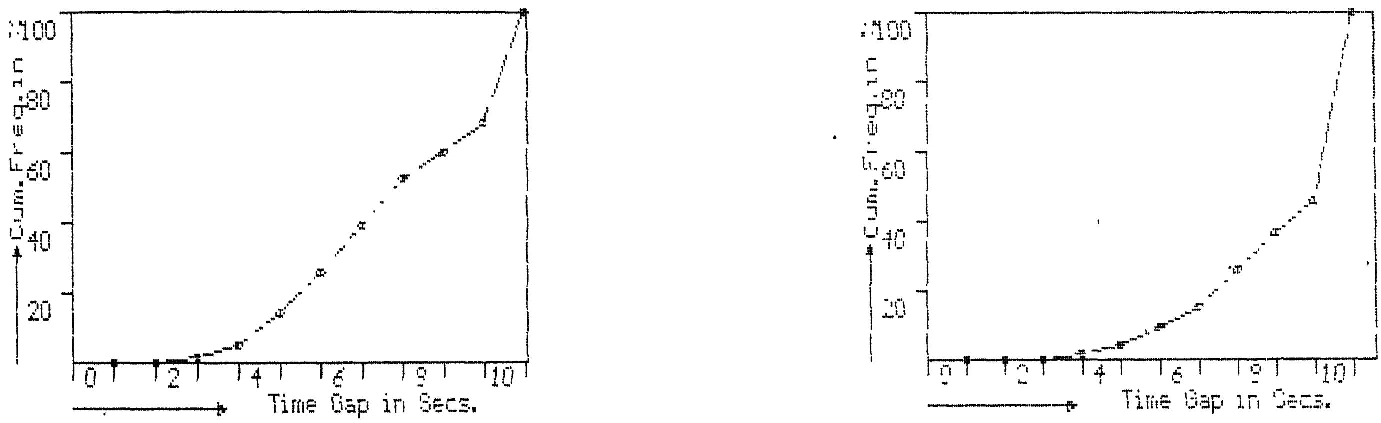
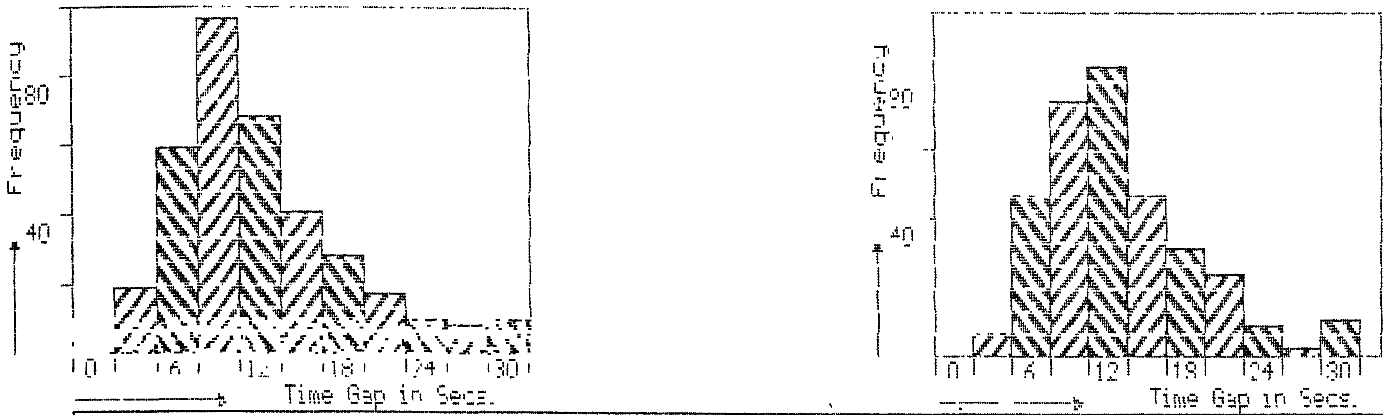


Fig. 5.8 : DISTRIBUTION OF TIME GAPS FROM LEVEL-UP TO END OF OVERTAKING (PLAIN TERRAIN)



DISTRIBUTION OF GAPS FROM START TO END OF OVERTAKING		
	FLYING OVERTAKINGS	ACCELERATIVE OVERTAKINGS
NO OF OBSERVATIONS	393	371
MEAN TIME GAP (SEC.)	13.87	14.65
STANDARD DEVIATION	6.95	6.13

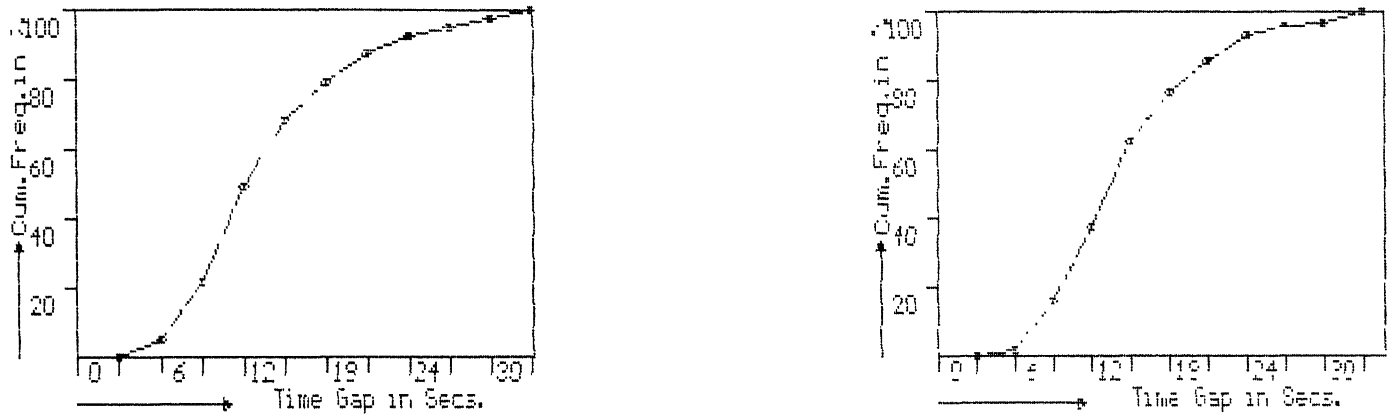


Fig. 5.9 : DISTRIBUTION OF TIME GAPS FROM START TO END OF OVERTAKING (PLAIN TERRAIN)

5.5 STATISTICS OF DERIVED PARAMETERS (PROGRAM ANALYSIS II)

The distributions of various derived parameters presented earlier in section 5.4 (Figs. 5.2 to 5.10) show wide dispersion. For a better understanding of the derived parameter values, it is desireable to study the parameters separately for each vehicle type as the vehicle type plays a major role in the overtaking behaviour. The statistics of the derived parameters are computed for six different vehicle types and shown in Tables 5.8 to 5.15. Mean, standard deviation and skewness coefficient are computed separately for flying and accelerative overtaking operation both in plain and rolling terrains. Gap statistics are further expressed both for time and space measurements.

The eight derived parameters as analysed in this study can be classified into two groups:

(i) Decision Parameters : These parameters contribute to the decision about the rejection or acceptance of an overtaking opportunity. These include the gaps for accepted and rejected opportunities.

(ii) Performance Parameters : These parameters describe the performance while executing an overtaking operation. These include:

- Gap at catch up point
- Gap while following
- Gap from start of overtaking to leveling up with the overtaken vehicle

- Gap from leveling up to end of overtaking operation
- Gap from start to end of overtaking operation

Besides the above two groups of derived parameters, the safety margin parameter is a combination of decision and performance parameters.

The above-mentioned performance parameters depend upon the characteristics of the overtaking and overtaken vehicles, and the driver behaviour. These explain the performance of the vehicle while executing the overtaking operation. The decision parameters are more critical and these also depend upon the characteristics of the oncoming obstruction besides the factors affecting the performance parameters.

Mean and standard deviation of the various derived parameters are represented in bar charts, shown in Figs. 5.11 to 5.18. These charts represent the statistics both for flying and accelerative overtakings. The statistics presented in these figures correspond to time gap measurements only for plain terrain.

Results for the oncoming time gaps for accepted opportunities(Table 5.10) show that the mean acceptable time gaps are higher for flying overtaking by about 2 to 4 seconds than those for the accelerative overtaking operations. This is because a following vehicle moving at slower speed is constantly on the look out for overtaking, and tends to accept smaller gaps. However, acceptable space gaps are almost close both for flying

and accelerative overtaking. Mean acceptable time gaps depend upon the type of vehicle executing the overtaking. These gaps are maximum for Trucks and minimum for Maruti Cars. For light vehicles like Cars, L.C.V.etc., acceptable time gaps for plain terrain are lower than those for the rolling terrain, whereas for heavy vehicles like Trucks and Buses the effect of terrain is insignificant.

The mean rejected time gap (Table 5.8) varies from 5 to 8 seconds for different vehicle types. The rejected time gap distributions depend upon the traffic volume of oncoming traffic stream. It may be desirable to evaluate the critical time gaps which are rejected most often by different vehicle types. This analysis is not carried out in this study.

When a vehicle catches up, gaps are estimated with respect to the test vehicle. These gaps shown in Table 5.9 and Figs. 5.12, show that these also depend upon the vehicle types, being highest for Trucks and lowest for Maruti Cars. For rolling terrain, these gaps are higher than those for the plain terrain as the speed gets reduced.

The gaps while following (Table 5.11) depend upon the type and speed of the vehicle being followed. The results indicate that vehicles maintain a mean headway of about 1.5 seconds.

The result of time gaps to execute the overtaking, from start to end of overtaking, shown in Table 5.14 and Fig 5.17, shows that the mean time gaps for overtaking manoeuvre varies from 10 to 18 seconds depending upon the vehicle types and type of overtaking.

These gaps are again more for the heavy vehicles. The total gap to execute overtaking is further divided in two components namely; from start to level up point and from level up to end of overtaking. The results for these components are shown in Table 5.12 to 5.13.

The gaps for the safety margin, that is, from the instant of end of overtaking operation to the instant when oncoming obstruction crosses, are presented in Table 5.15. The results indicate that light vehicles have less safety margin as because of their easy manoeuvreability these vehicle can take more risk.

The statistics for various derived parameters of different vehicle types as explained above could be used in designing the road geometries like stopping and overtaking sight distances. Now we have a better understanding of the vehicle behaviour while overtaking, and overall critical gaps could be estimated and used in designing the road geometries.

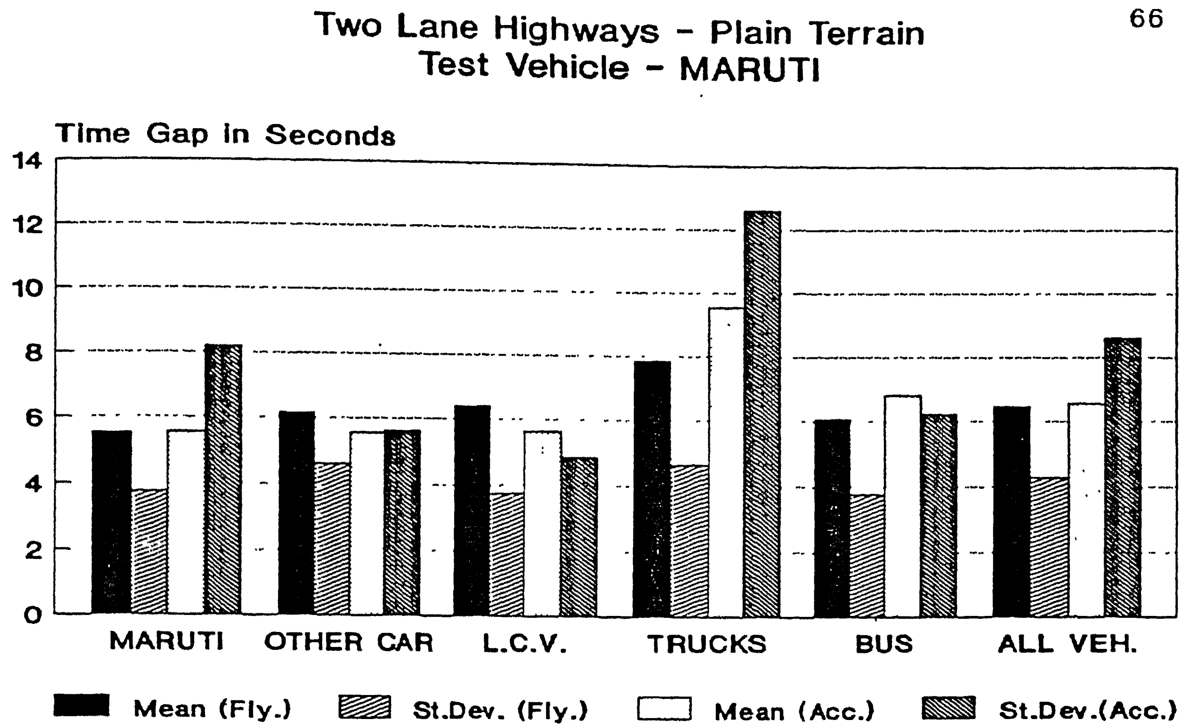


Fig. 5.11 Distribution of oncoming time gap for Rejected Opportunities

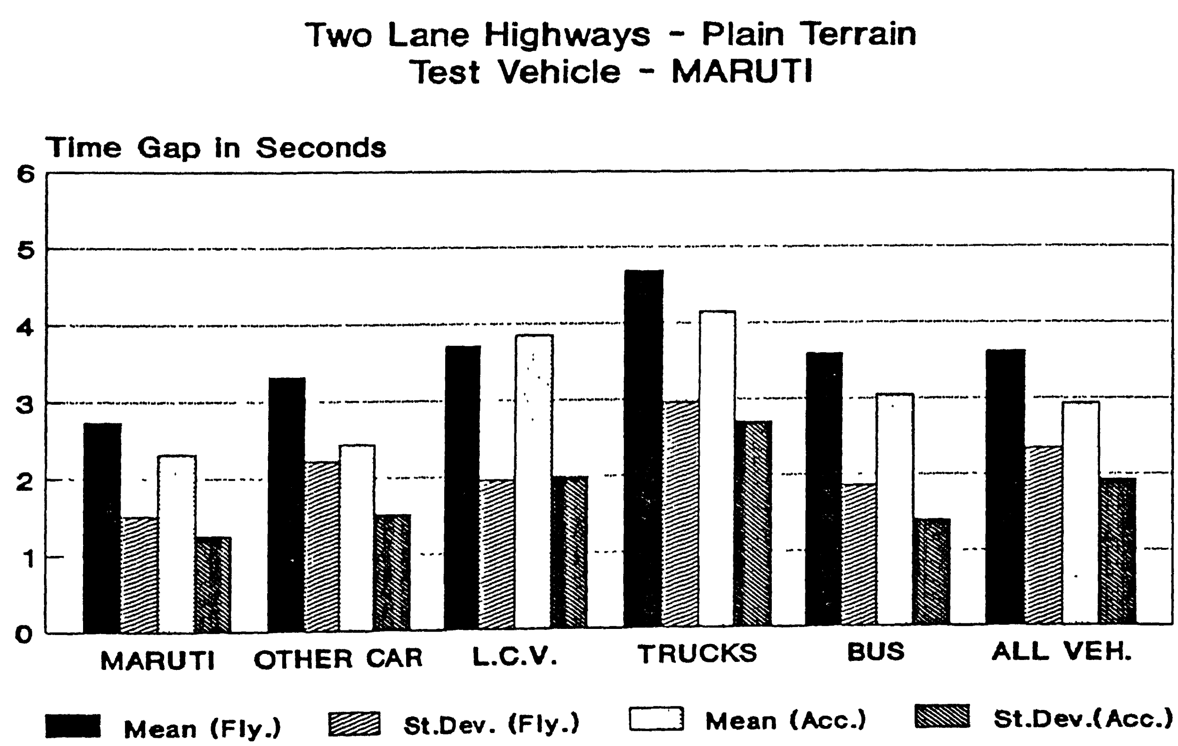


Fig. 5.12 Distribution of time gap for Catch-Up Position

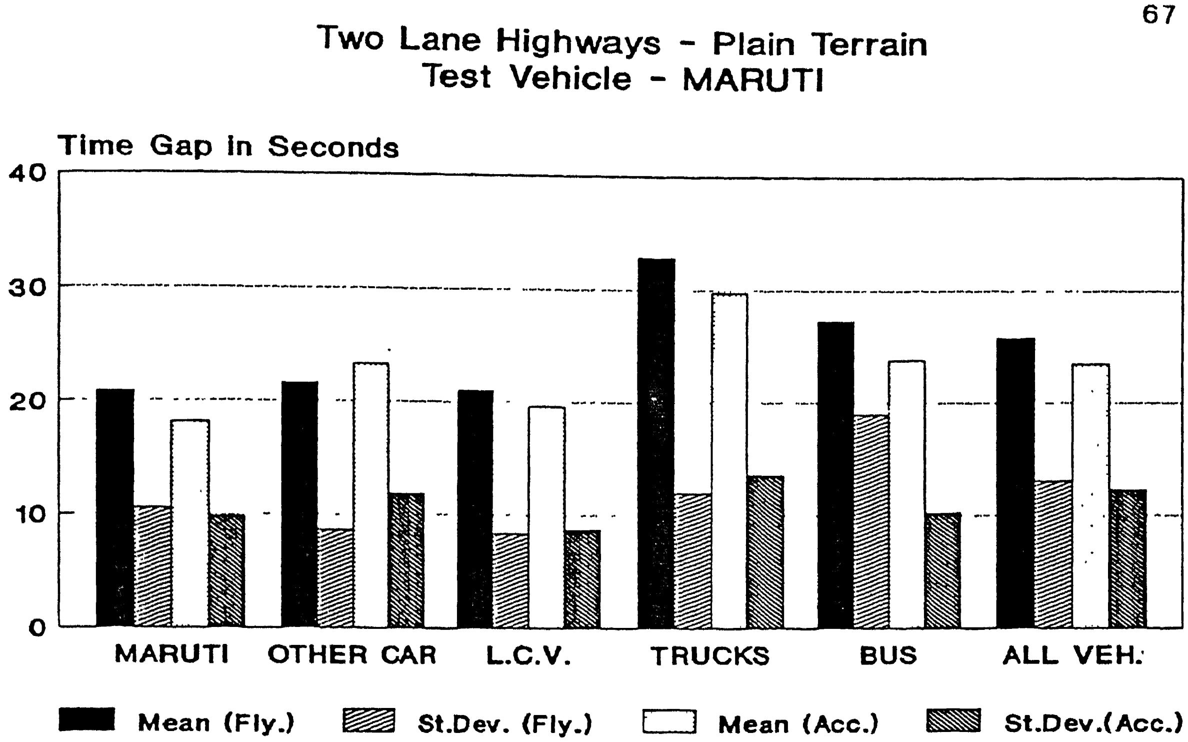


Fig. 5.13 Distribution of oncoming time gap for Accepted Opportunities

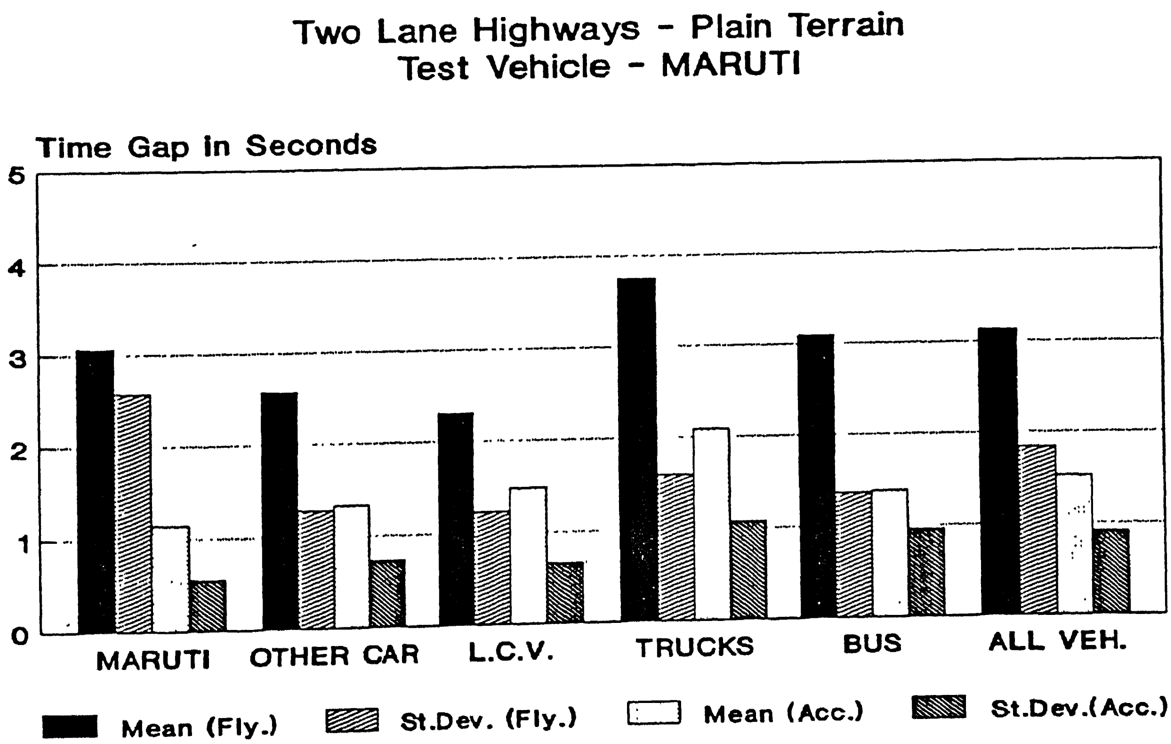


Fig. 5.14 Distribution of time gap at Start Of Overtaking

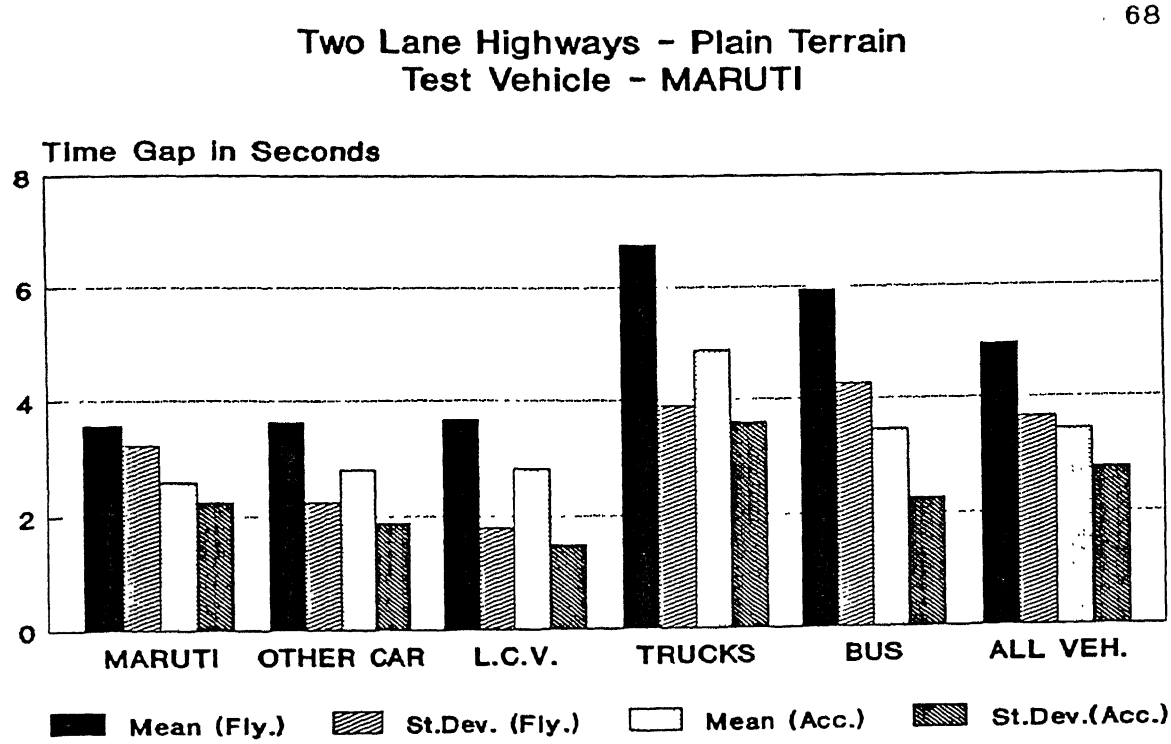


Fig. 5.15 Distribution of time gap from Start To Level-Up

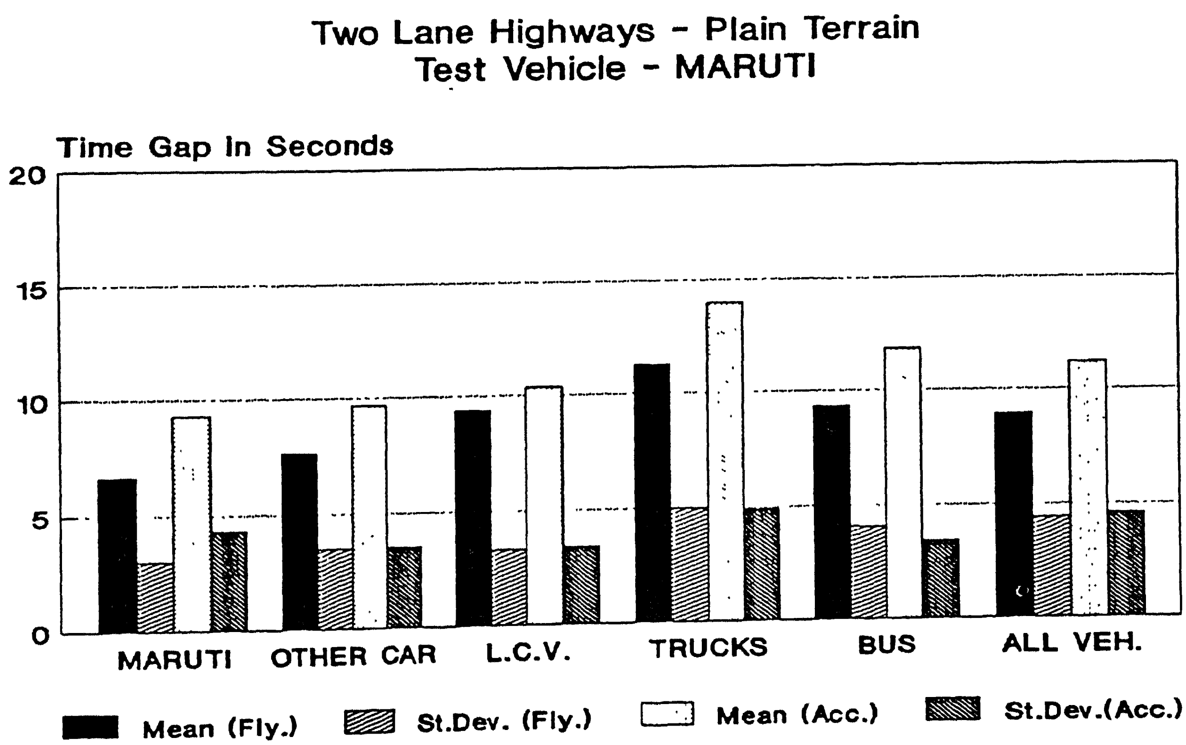


Fig. 5.16 Distribution of time gap from Level-Up To End Of Overtaking

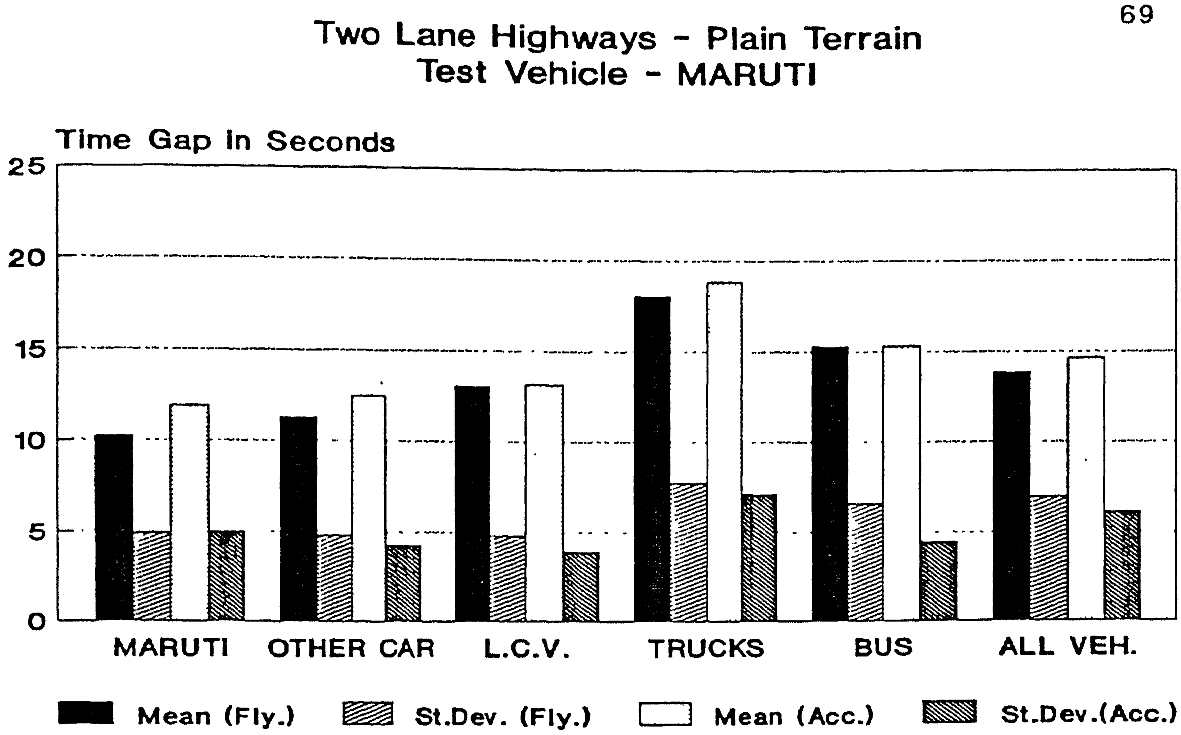


Fig. 5.17 Distribution of time gap from Start to End Of Overtaking

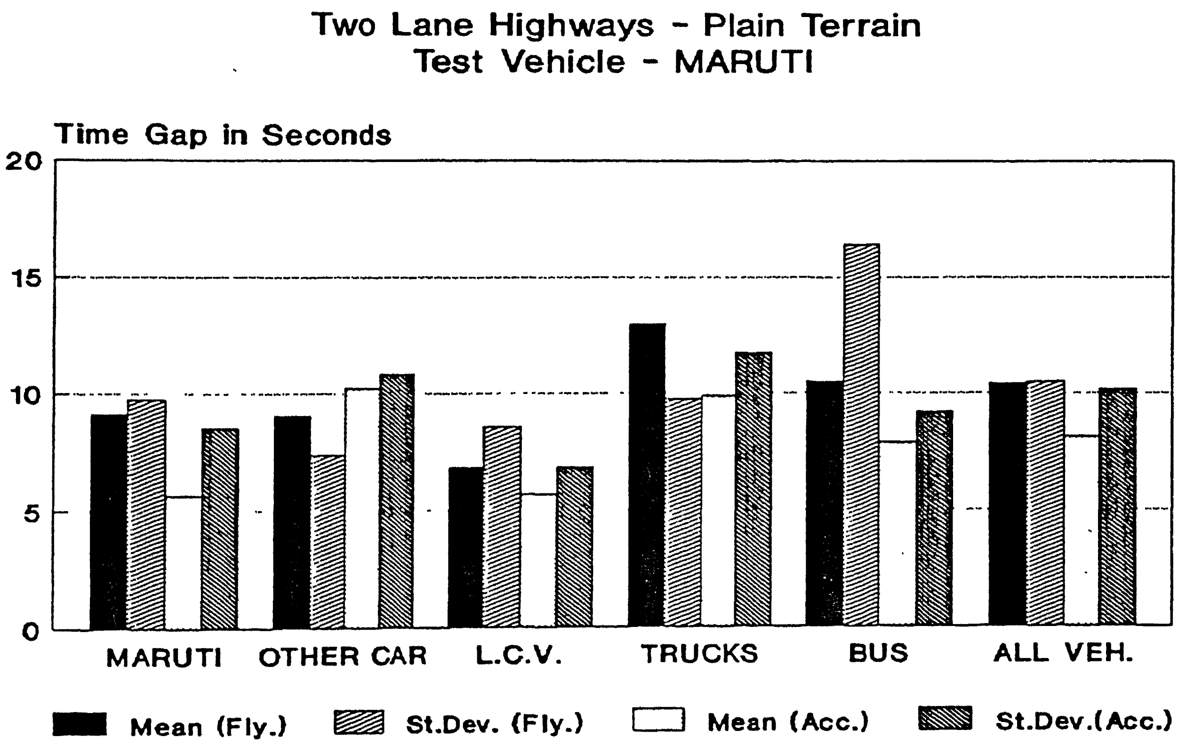


Fig. 5.18 Distribution Of time gap between End Of Overtaking and Oncoming Vehicle (Safety Margin)

TABLE 5.8 : DISTRIBUTION OF ONCOMING GAPS FOR REJECTED OPPORTUNITIES

TIME GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	5.54	3.76	1.72	5.55	8.19	10.72
OTHER CARS	6.16	4.62	2.35	5.56	5.64	2.90
L.C.V.	6.42	3.76	1.03	5.64	4.87	3.78
TRUCKS	7.85	4.66	1.40	9.54	12.59	5.85
BUS	6.07	3.77	2.22	6.81	6.24	2.31
ALL VEHICLES	6.48	4.29	1.81	6.57	8.60	7.90
ROLLING TERRAIN						
MARUTI	7.71	10.57	2.91	4.73	2.78	0.40
OTHER CARS	6.53	3.54	1.06	7.16	5.30	1.13
L.C.V.	4.18	1.92	0.85	6.20	4.57	0.71
TRUCKS	8.05	4.93	1.55	9.67	5.55	0.85
BUS	6.43	3.26	1.68	8.18	5.69	1.37
ALL VEHICLES	7.20	5.70	3.68	7.60	5.29	1.13

SPACE GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	196.69	143.87	2.06	200.83	242.56	7.27
OTHER CARS	208.39	171.75	2.48	208.34	218.90	3.09
L.C.V.	215.89	133.88	1.29	187.15	176.48	4.09
TRUCKS	227.80	151.23	2.01	285.20	334.44	5.02
BUS	205.92	130.51	2.23	270.93	270.29	2.38
ALL VEHICLES	210.95	149.13	2.19	228.52	261.86	5.28
ROLLING TERRAIN						
MARUTI	230.45	291.56	2.94	176.33	124.57	0.60
OTHER CARS	201.44	132.93	1.61	220.04	168.71	1.52
L.C.V.	120.89	59.50	0.60	225.44	187.28	1.24
TRUCKS	212.29	151.84	2.07	245.17	145.78	0.79
BUS	184.74	101.80	1.54	240.94	189.73	2.03
ALL VEHICLES	205.03	170.24	3.41	225.97	162.77	1.44

TABLE 5.9 : DISTRIBUTION OF GAPS AT CATCH-UP POINT

TIME GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	2.74	1.51	1.98	2.32	1.26	1.85
OTHER CARS	3.32	2.22	1.64	2.44	1.52	1.50
L.C.V.	3.71	1.96	1.58	3.85	1.98	1.41
TRUCKS	4.68	2.97	1.89	4.14	2.70	2.46
BUS	3.59	1.86	1.19	3.05	1.40	1.80
ALL VEHICLES	3.62	2.35	2.13	2.94	1.93	2.67
ROLLING TERRAIN						
MARUTI	3.06	1.83	1.35	2.38	1.00	0.11
OTHER CARS	3.37	1.77	0.84	3.09	1.59	0.91
L.C.V.	3.58	2.13	0.36	1.87	1.68	2.13
TRUCKS	5.24	3.02	1.00	5.76	3.54	1.09
BUS	3.11	1.71	1.18	3.30	1.67	1.26
ALL VEHICLES	4.04	2.53	1.42	3.64	2.74	1.89

SPACE GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	33.57	16.03	1.49	29.69	14.56	1.38
OTHER CARS	38.68	22.25	0.98	31.61	17.90	0.81
L.C.V.	43.83	18.86	0.81	46.04	18.46	0.68
TRUCKS	45.71	21.85	1.04	42.77	20.71	1.38
BUS	42.20	18.23	0.89	40.99	16.69	0.89
ALL VEHICLES	40.20	20.17	1.13	35.50	18.36	1.17
ROLLING TERRAIN						
MARUTI	34.70	20.38	1.10	28.77	13.39	0.05
OTHER CARS	34.80	14.96	0.38	32.84	14.21	0.55
L.C.V.	35.19	17.83	0.48	19.84	14.20	2.53
TRUCKS	46.51	22.97	0.79	49.88	24.99	0.79
BUS	33.72	19.20	0.99	35.65	20.32	1.20
ALL VEHICLES	39.31	20.40	0.99	35.73	21.36	1.25

TABLE 5.10 : DISTRIBUTION OF ONCOMING GAPS FOR ACCEPTED OPPORTUNITIES

TIME GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	20.90	10.55	1.63	18.15	9.77	1.70
OTHER CARS	21.64	8.61	0.28	23.36	11.83	0.99
L.C.V.	21.04	8.34	0.14	19.62	8.70	0.48
TRUCKS	32.88	11.96	1.01	29.76	13.55	1.01
BUS	27.29	18.98	3.30	23.86	10.20	0.31
ALL VEHICLES	25.85	13.05	2.11	23.53	12.22	1.15
ROLLING TERRAIN						
MARUTI	25.08	12.03	1.62	20.76	9.56	0.35
OTHER CARS	24.23	9.37	0.74	21.56	10.69	1.68
L.C.V.	27.44	8.37	0.02	24.65	9.26	-0.18
TRUCKS	30.68	10.91	0.29	32.51	12.23	0.16
BUS	29.77	10.05	-0.44	19.81	11.04	1.05
ALL VEHICLES	27.50	10.77	0.61	25.72	12.32	0.71

SPACE GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	617.31	303.67	1.72	624.98	367.01	3.19
OTHER CARS	615.58	275.53	1.64	737.73	381.96	1.40
L.C.V.	624.16	182.03	-0.20	628.65	207.12	0.32
TRUCKS	871.56	407.84	2.20	839.78	465.90	1.76
BUS	776.34	578.40	3.29	786.81	357.52	0.56
ALL VEHICLES	721.55	392.29	2.87	734.28	399.06	1.98
ROLLING TERRAIN						
MARUTI	725.33	369.15	1.84	583.68	269.25	0.74
OTHER CARS	647.90	345.24	2.43	565.92	267.65	0.90
L.C.V.	731.23	377.29	0.39	653.30	272.04	0.62
TRUCKS	749.97	386.27	1.48	794.75	411.91	1.27
BUS	686.14	334.75	0.86	472.21	188.58	0.50
ALL VEHICLES	705.25	364.48	1.70	654.10	345.10	1.50

TABLE 5.11 : DISTRIBUTION OF GAPS AT START OF OVERTAKING

TIME GAP DISTRIBUTION						
	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	3.06	2.57	4.32	1.14	0.55	1.56
OTHER CARS	2.57	1.28	0.84	1.33	0.73	1.80
L.C.V.	2.31	1.23	0.81	1.48	0.66	0.77
TRUCKS	3.75	1.59	1.04	2.09	1.07	1.14
BUS	3.09	1.36	0.65	1.38	0.95	2.29
ALL VEHICLES	3.13	1.84	3.27	1.52	0.91	1.75
ROLLING TERRAIN						
MARUTI	2.74	1.54	1.65	1.30	0.67	1.55
OTHER CARS	2.99	1.70	1.65	1.39	0.60	1.35
L.C.V.	4.01	4.16	2.61	1.67	0.77	0.43
TRUCKS	3.84	1.70	1.08	2.35	1.07	1.35
BUS	3.24	1.73	1.51	1.17	0.30	0.67
ALL VEHICLES	3.33	1.92	2.46	1.74	0.95	1.69

SPACE GAP DISTRIBUTION						
	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	30.72	12.18	0.51	14.16	6.97	2.89
OTHER CARS	27.73	11.03	0.51	15.83	7.67	1.99
L.C.V.	25.77	9.60	-0.07	17.39	6.79	0.99
TRUCKS	36.12	11.82	0.78	21.24	9.54	1.03
BUS	32.30	11.29	0.38	15.99	9.42	2.47
ALL VEHICLES	31.69	12.01	0.56	17.08	8.72	1.79
ROLLING TERRAIN						
MARUTI	29.60	10.56	0.88	14.59	7.09	1.78
OTHER CARS	28.65	11.37	0.88	14.75	6.83	2.03
L.C.V.	32.47	16.02	0.16	16.81	5.46	0.57
TRUCKS	33.20	11.76	1.25	20.53	8.44	1.03
BUS	28.23	10.84	0.87	11.51	3.00	1.27
ALL VEHICLES	30.53	11.71	0.96	16.79	7.86	1.47

TABLE 5.12 : DISTRIBUTION OF GAPS FROM START TO LEVEL-UP

TIME GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	3.57	3.23	3.49	2.59	2.25	2.80
OTHER CARS	3.63	2.25	1.99	2.81	1.88	1.59
L.C.V.	3.67	1.80	1.00	2.82	1.49	1.87
TRUCKS	6.76	3.89	2.06	4.87	3.60	1.64
BUS	5.94	4.27	3.37	3.46	2.26	1.33
ALL VEHICLES	4.95	3.66	2.61	3.44	2.77	2.22
ROLLING TERRAIN						
MARUTI	3.28	2.11	2.03	2.40	1.07	0.55
OTHER CARS	3.67	1.97	1.44	2.40	1.17	1.39
L.C.V.	4.81	3.65	1.45	2.66	1.85	0.73
TRUCKS	5.48	3.47	2.20	4.31	2.97	2.29
BUS	5.06	2.67	1.03	2.81	1.59	1.82
ALL VEHICLES	4.48	2.91	2.20	3.20	2.28	2.95

SPACE GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	77.39	34.07	2.06	53.99	32.01	2.47
OTHER CARS	74.77	34.34	2.04	56.64	26.80	1.35
L.C.V.	76.90	25.24	1.16	60.43	27.10	1.66
TRUCKS	111.16	47.83	1.45	76.69	42.10	1.59
BUS	102.40	46.13	2.45	63.53	35.57	1.53
ALL VEHICLES	91.11	43.44	1.87	63.04	35.62	1.91
ROLLING TERRAIN						
MARUTI	74.87	29.85	1.50	49.67	18.82	1.39
OTHER CARS	72.83	25.99	1.30	47.19	19.87	1.59
L.C.V.	92.22	51.56	0.87	50.81	20.01	0.63
TRUCKS	90.19	37.55	1.69	67.27	33.88	1.52
BUS	83.90	40.45	1.53	45.65	16.69	1.10
ALL VEHICLES	81.63	35.16	1.69	55.51	27.44	1.96

TABLE 5.13 : DISTRIBUTION OF GAPS FROM LEVEL-UP TO END OF OVERTAKING

TIME GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	6.68	3.00	1.40	9.32	4.32	1.87
OTHER CARS	7.66	3.49	1.30	9.68	3.52	0.94
L.C.V.	9.38	3.32	0.73	10.36	3.38	1.07
TRUCKS	11.27	5.00	1.89	13.98	4.89	0.61
BUS	9.33	4.07	3.29	11.85	3.42	1.47
ALL VEHICLES	8.93	4.41	1.95	11.20	4.58	1.09
ROLLING TERRAIN						
MARUTI	6.75	3.47	1.31	7.93	1.96	0.20
OTHER CARS	8.16	4.62	2.90	9.58	6.85	4.27
L.C.V.	9.08	3.92	0.68	9.53	5.01	0.65
TRUCKS	10.25	3.85	1.17	13.23	5.17	0.70
BUS	9.79	3.44	0.68	11.30	5.24	1.33
ALL VEHICLES	8.92	4.18	1.67	10.91	5.72	2.61

SPACE GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	128.07	42.38	1.08	161.08	70.57	2.34
OTHER CARS	134.09	51.94	1.94	160.14	53.15	0.89
L.C.V.	166.79	50.18	1.65	173.76	50.66	0.85
TRUCKS	167.99	54.88	1.27	192.04	62.43	0.73
BUS	152.34	53.32	2.42	190.26	59.61	1.38
ALL VEHICLES	148.05	53.49	1.53	175.22	63.37	1.41
ROLLING TERRAIN						
MARUTI	120.89	45.55	1.03	129.61	34.02	0.03
OTHER CARS	131.04	55.20	2.55	136.95	60.86	2.53
L.C.V.	152.27	51.47	0.96	159.00	75.33	1.26
TRUCKS	150.24	49.48	1.57	173.08	58.37	0.57
BUS	143.36	52.89	1.14	139.35	51.07	0.51
ALL VEHICLES	138.75	52.18	1.70	151.24	58.50	1.38

TABLE 5.14 : DISTRIBUTION OF GAPS FROM START TO END OF OVERTAKING

TIME GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	10.25	4.88	1.64	11.91	4.97	1.23
OTHER CARS	11.30	4.81	1.49	12.49	4.22	0.61
L.C.V.	13.05	4.79	0.84	13.18	3.89	0.83
TRUCKS	18.03	7.74	2.20	18.84	7.12	0.94
BUS	15.27	6.57	2.05	15.30	4.41	1.11
ALL VEHICLES	13.87	6.95	1.99	14.65	6.13	1.25
ROLLING TERRAIN						
MARUTI	10.03	4.85	1.78	10.32	2.47	0.23
OTHER CARS	11.83	5.58	2.27	11.98	7.04	3.97
L.C.V.	13.89	6.48	1.44	12.19	5.48	0.74
TRUCKS	15.73	6.26	1.55	17.54	7.03	1.42
BUS	14.84	5.45	0.92	14.11	6.39	1.59
ALL VEHICLES	13.39	6.12	1.55	14.11	6.96	2.23

SPACE GAP DISTRIBUTION

	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	196.67	57.01	1.19	209.35	76.63	1.58
OTHER CARS	204.58	77.74	2.59	209.29	61.23	0.66
L.C.V.	237.84	72.82	2.14	224.60	52.09	0.38
TRUCKS	271.95	87.12	1.72	261.60	83.89	1.08
BUS	248.11	68.87	1.09	248.23	73.78	1.04
ALL VEHICLES	232.43	81.48	1.73	231.50	77.28	1.18
ROLLING TERRAIN						
MARUTI	189.92	61.72	1.27	169.71	46.09	0.58
OTHER CARS	207.65	123.95	5.63	175.63	69.04	2.60
L.C.V.	240.54	83.18	1.54	202.04	72.42	1.05
TRUCKS	232.42	72.20	1.39	234.73	80.21	0.83
BUS	218.42	87.89	1.49	177.59	55.83	0.52
ALL VEHICLES	216.44	93.17	4.51	199.34	74.90	1.41

TABLE 5.15 : DISTRIBUTION OF GAPS BETWEEN END OF OVERTAKING AND ONCOMING VEHICLE - SAFTEY MARGIN

TIME GAP DISTRIBUTION						
	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (Sec)	Standard Deviation	Skew. Coeff.	Mean (Sec)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	9.13	9.74	1.91	5.67	8.53	0.50
OTHER CARS	9.06	7.39	0.13	10.21	10.83	1.19
L.C.V.	6.84	8.57	-0.76	5.70	6.84	0.41
TRUCKS	12.98	9.74	1.11	9.87	11.74	1.84
BUS	10.48	16.42	3.63	7.87	9.17	-0.26
ALL VEHICLES	10.41	10.49	2.57	8.13	10.16	1.34
ROLLING TERRAIN						
MARUTI	13.68	10.11	1.54	9.79	9.05	0.28
OTHER CARS	10.90	7.93	0.91	8.89	7.00	0.22
L.C.V.	11.54	6.25	0.08	11.63	5.45	-0.77
TRUCKS	13.04	9.32	0.60	13.80	10.61	1.09
BUS	13.31	6.87	-0.20	5.11	6.74	0.64
ALL VEHICLES	12.45	8.65	0.92	10.74	9.19	1.02
SPACE GAP DISTRIBUTION						
	FLYING OVERTAKING			ACCELERATIVE OVERTAKING		
	Mean (m)	Standard Deviation	Skew. Coeff.	Mean (m)	Standard Deviation	Skew. Coeff.
PLAIN TERRAIN						
MARUTI	149.63	182.23	2.67	103.13	195.99	1.13
OTHER CARS	126.54	112.22	1.00	188.31	242.49	2.31
L.C.V.	91.82	156.58	-1.30	95.80	115.51	0.55
TRUCKS	205.10	221.98	2.44	165.13	225.47	1.76
BUS	170.04	327.79	3.81	148.79	203.77	0.05
ALL VEHICLES	161.54	209.25	3.52	144.36	212.96	1.66
ROLLING TERRAIN						
MARUTI	231.73	202.62	2.23	149.17	160.91	0.86
OTHER CARS	159.68	168.00	3.37	131.01	125.50	1.15
L.C.V.	181.67	141.45	1.47	165.00	75.21	0.29
TRUCKS	196.17	212.20	2.37	205.94	208.07	1.59
BUS	176.10	134.58	1.07	55.21	63.67	0.37
ALL VEHICLES	187.39	186.15	2.61	157.90	168.31	1.82

5.6 STUDY OF GAP ACCEPTANCE (PROGRAM ANALYSIS III)

5.6.1 INTRODUCTION

Video recordings of the overtaking manoeuvres were done on a sufficiently large scale with the primary objective of estimating the probability of overtaking as a function of gap size for various types of vehicles. This estimated probability is a major input to the Traffic Interaction Model of the Simulation Model.

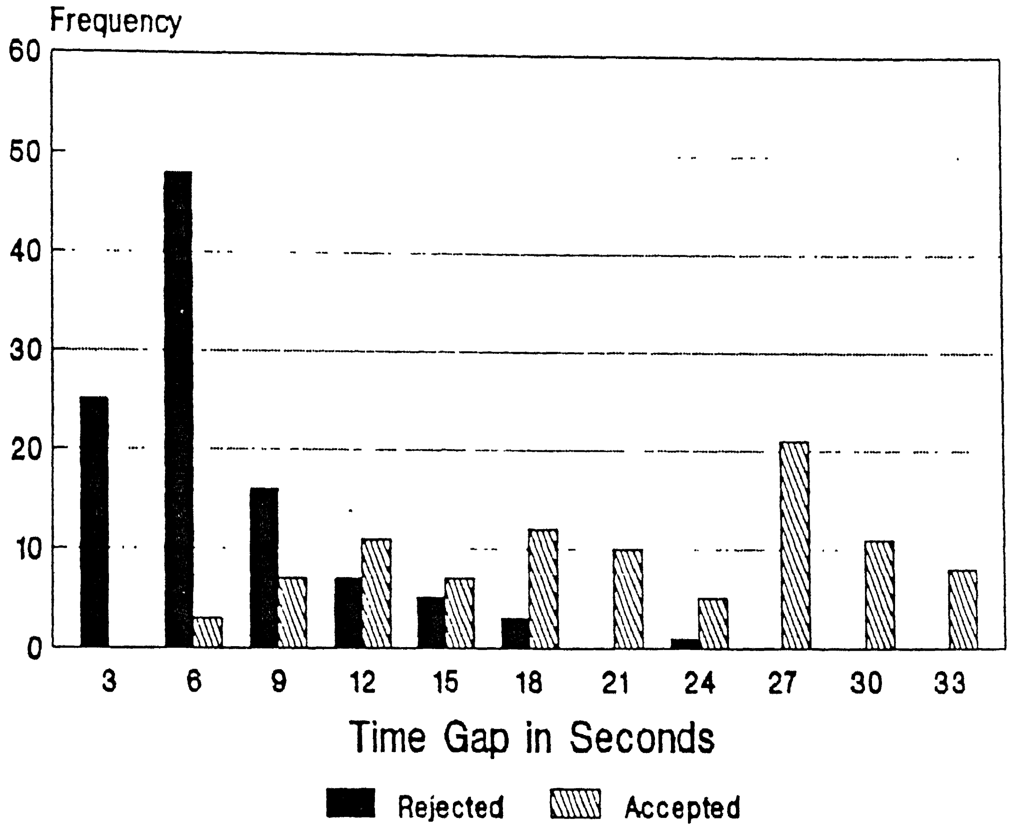
This analysis determines the number of accepted/rejected gaps for different combination of vehicles involved. The decision to accept or reject a certain gap depends upon:-

- Type and speed of overtaking vehicle
- Type and speed of overtaken vehicle
- Type and speed of oncoming vehicle
- Sight distance restriction, if any,
- Nature of overtaking - Flying / Accelerative

For this analysis Maruti Van is being overtaken by other vehicles. The speed of the oncoming vehicle determines the available closing gap. The type of the oncoming vehicle is not separately included in the analysis. The frequency distributions for the accepted and rejected gap by different types of vehicles, both for flying and accelerative overtaking manoeuvre, are determined and are presented in Figs. 5.19 - 5.24 for plain terrain with time gap observations.

Test Vehicle - MARUTI

Flying Overtaking



Accelerative Overtaking

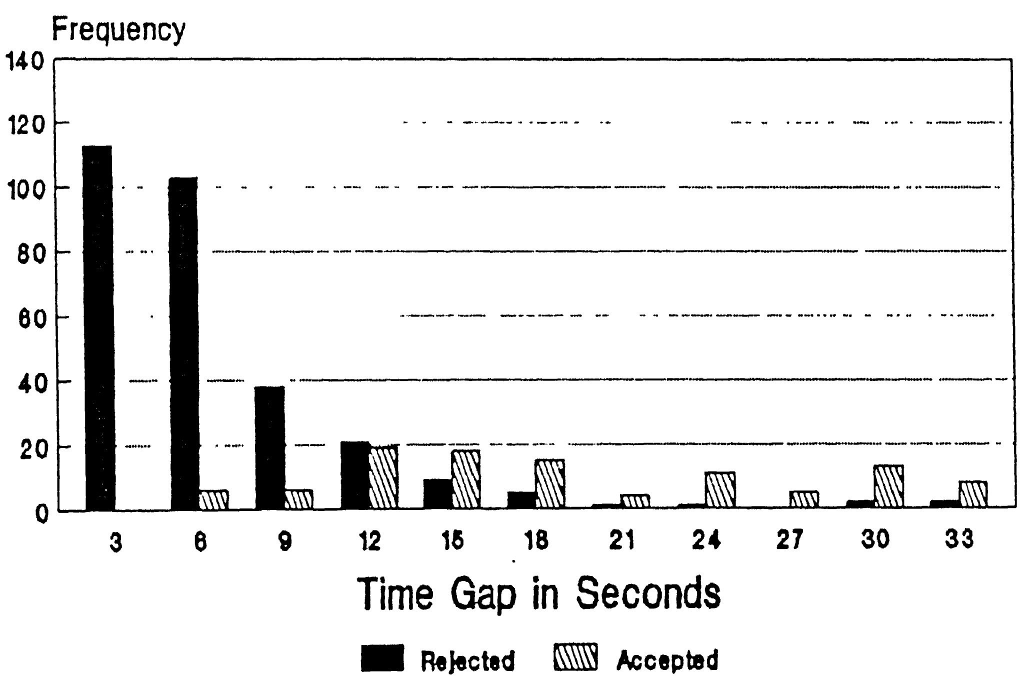
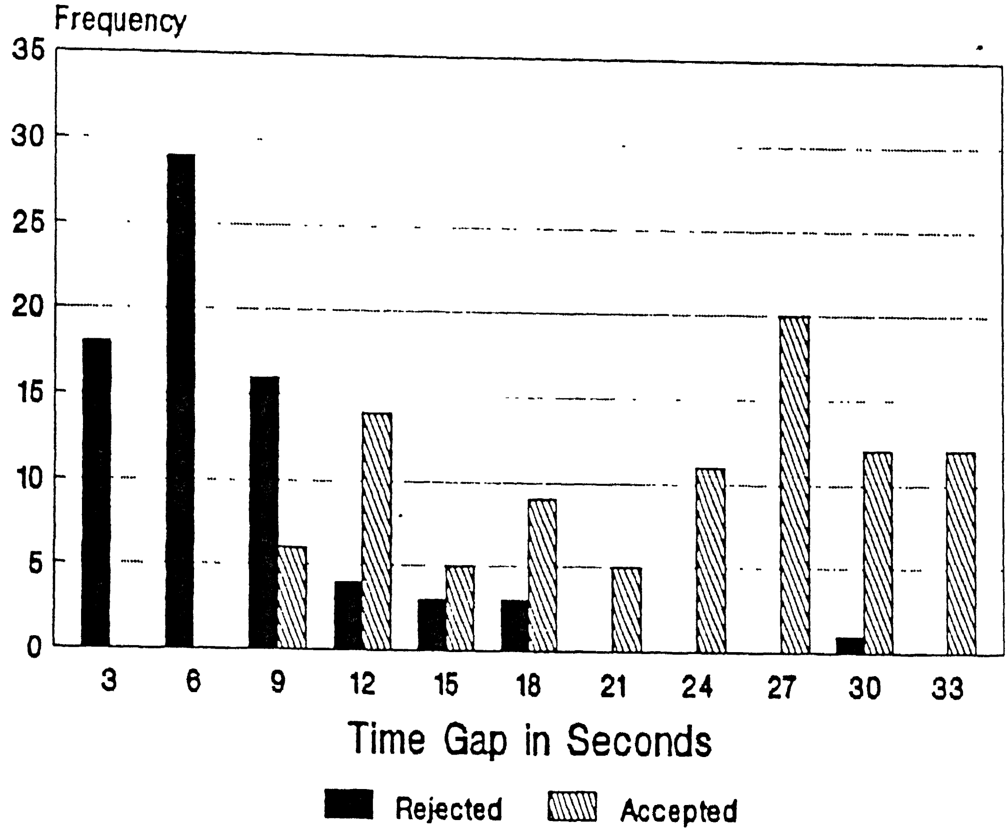


Fig. 5.19 Frequency Distribution of Rejected / Accepted Opportunities for Maruti

Test Vehicle - MARUTI

Flying Overtaking



Accelerative Overtaking

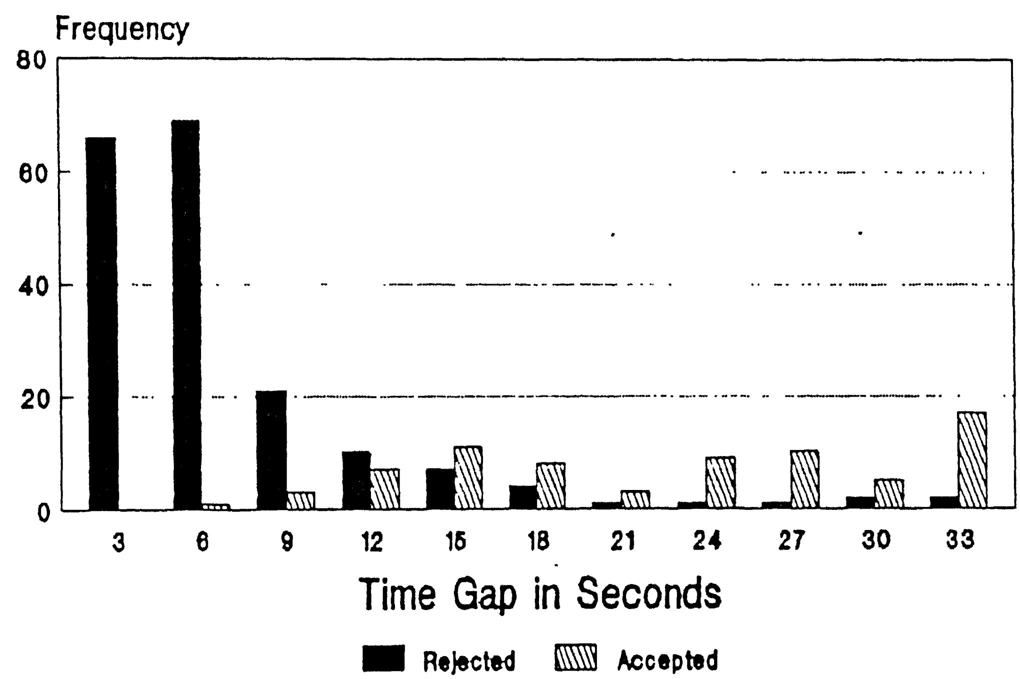
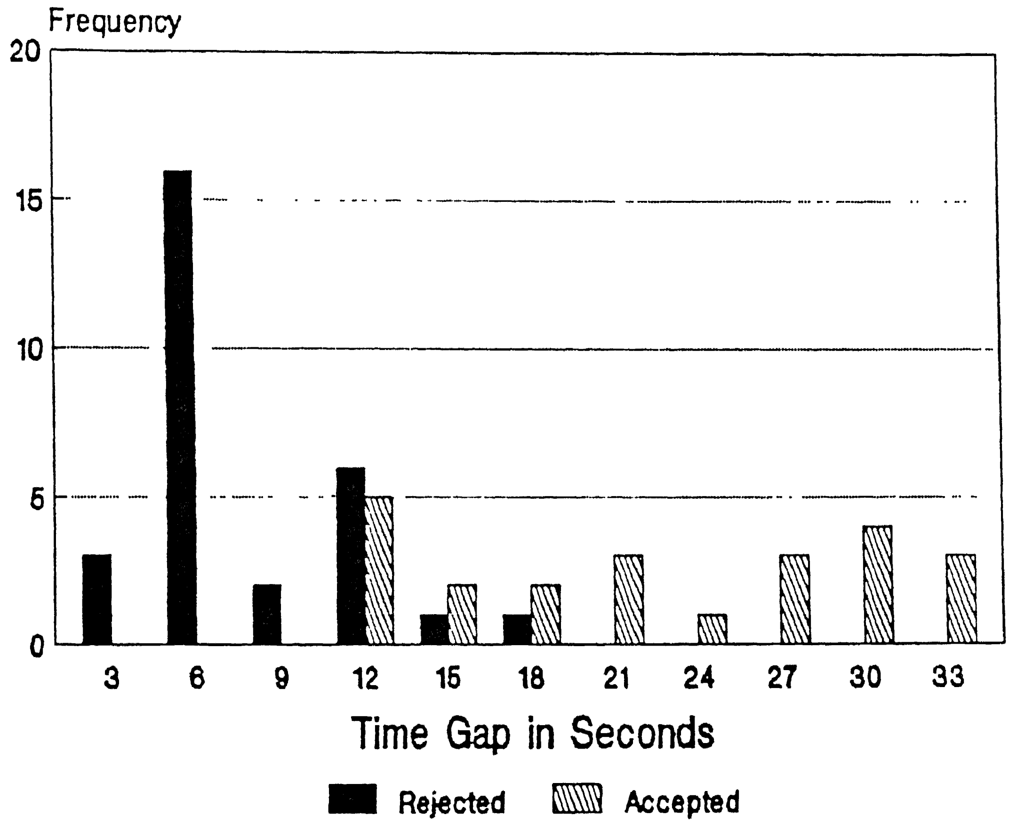


Fig. 5.20 Frequency Distribution of Rejected / Accepted Opportunities for Other Cars

Two Lane Highways - Plain Terrain
Test Vehicle - MARUTI

Flying Overtaking



Accelerative Overtaking

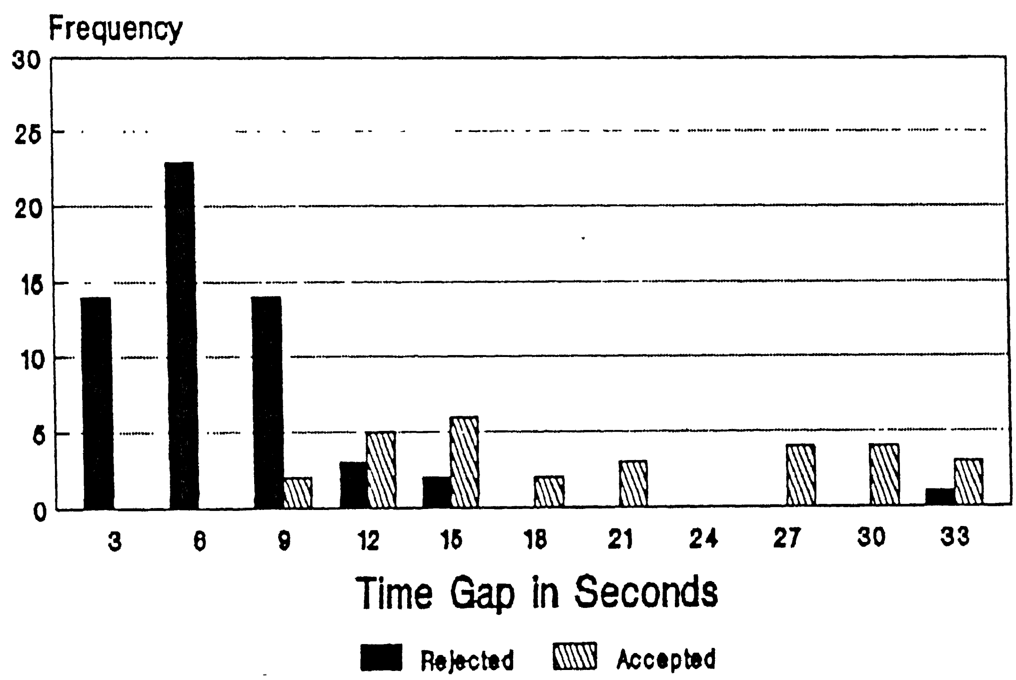
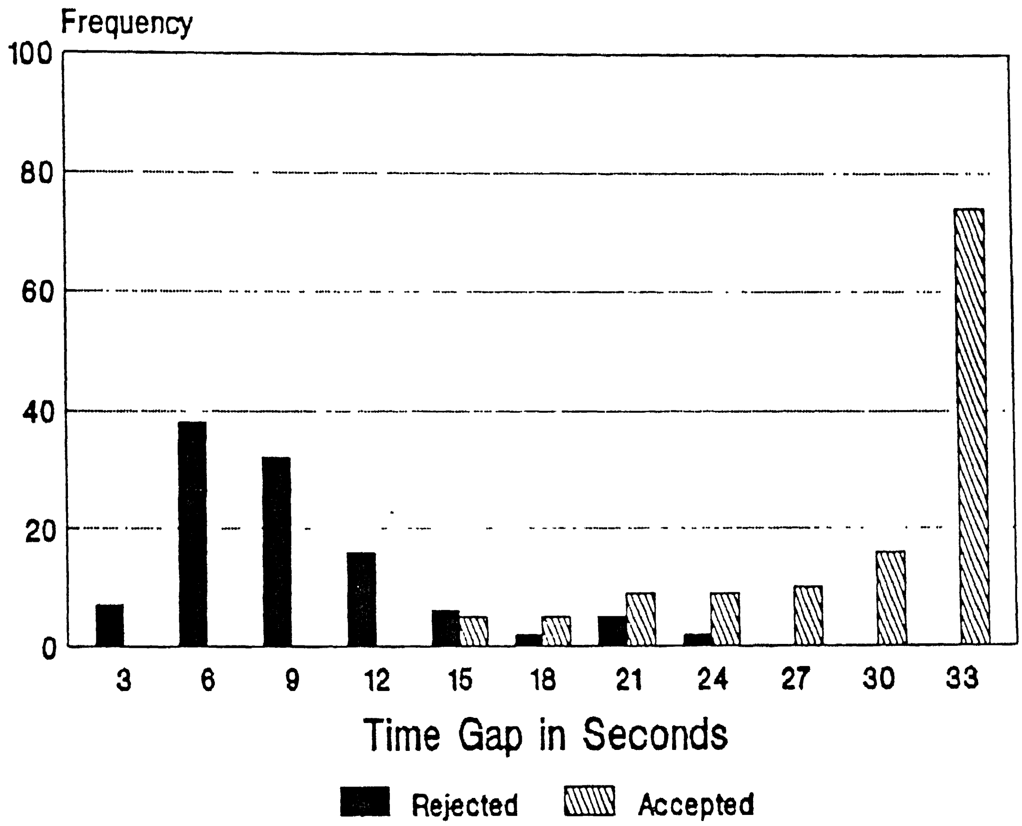


Fig. 5.21 Frequency Distribution of Rejected / Accepted Opportunities for L.C.V.

Two Lane Highways - Plain Terrain
Test Vehicle - MARUTI

Flying Overtaking



Accelerative Overtaking

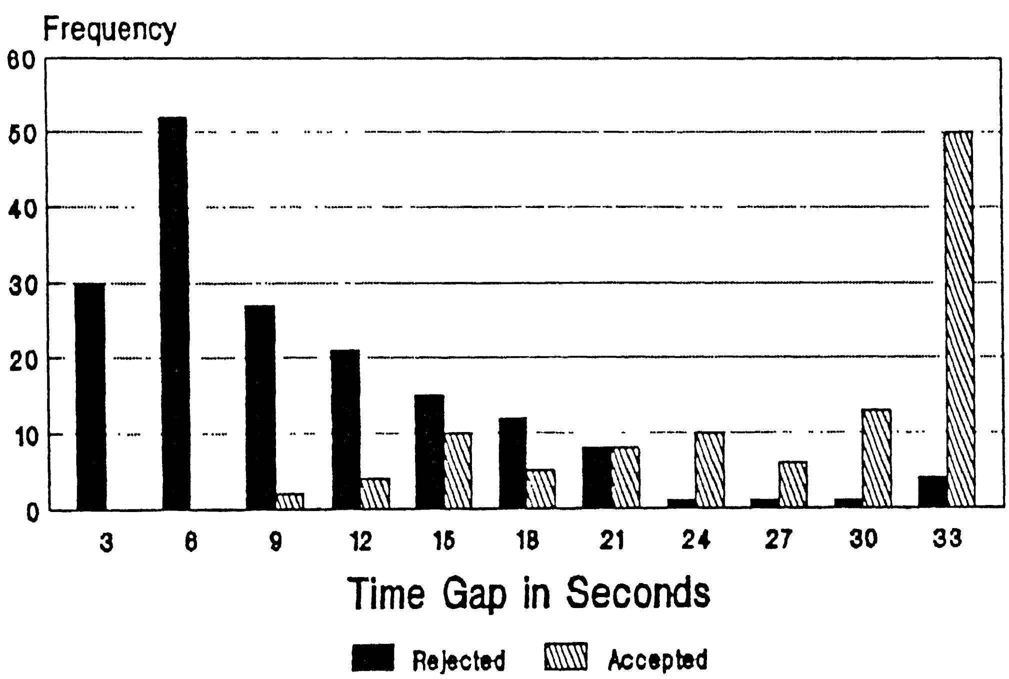
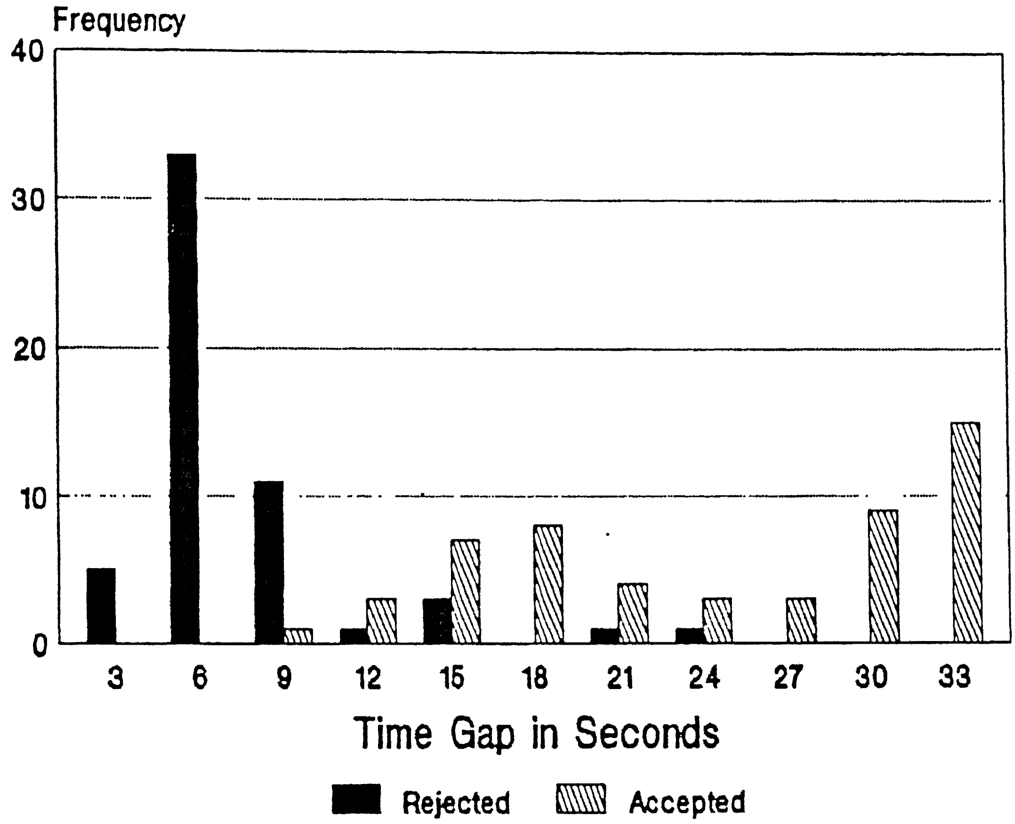


Fig. 5.22 Frequency Distribution of Rejected / Accepted Opportunities for Truck

Two Lane Highways - Plain Terrain
Test Vehicle - MARUTI

Flying Overtaking



Accelerative Overtaking

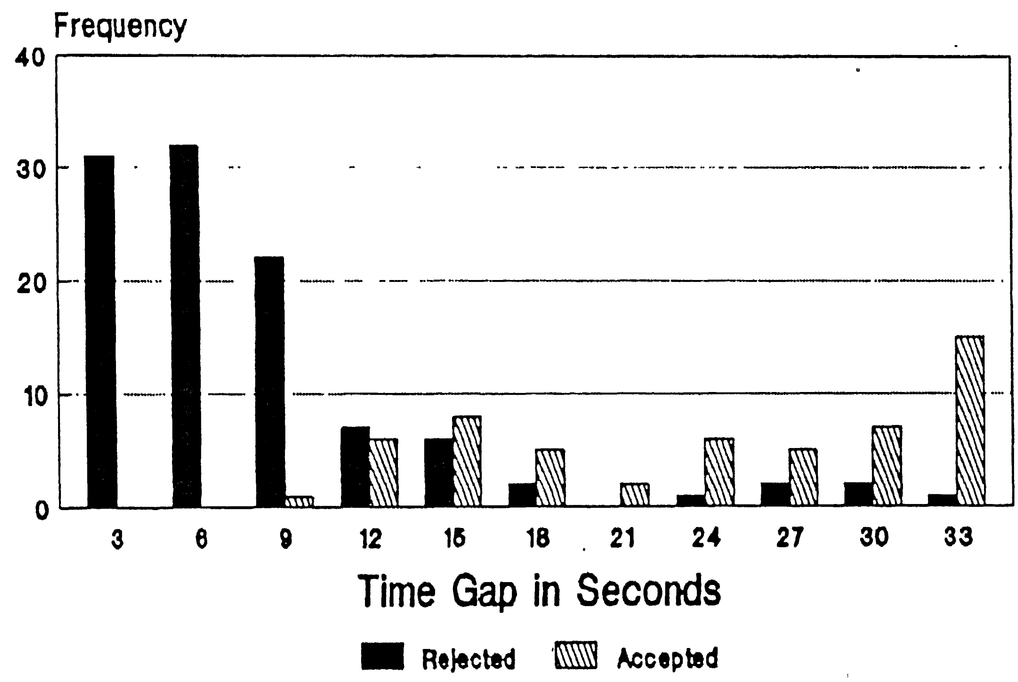
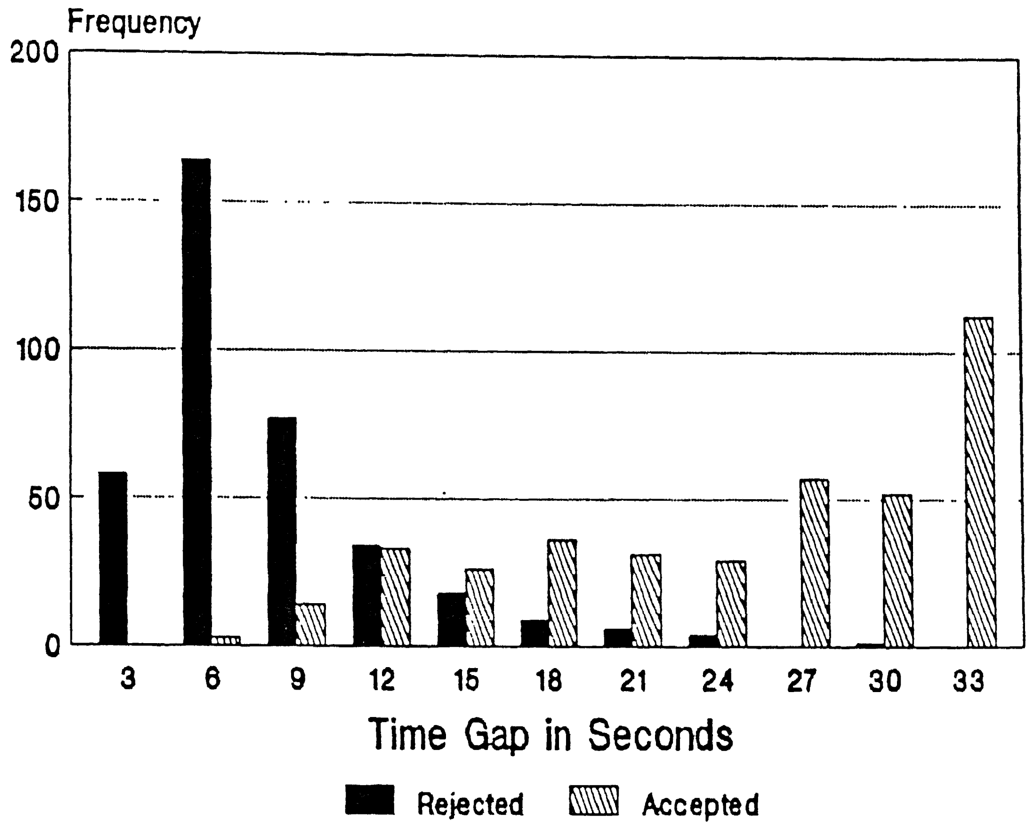


Fig. 5.23 Frequency Distribution of Rejected / Accepted Opportunities for Bus

Flying Overtaking



Accelerative Overtaking

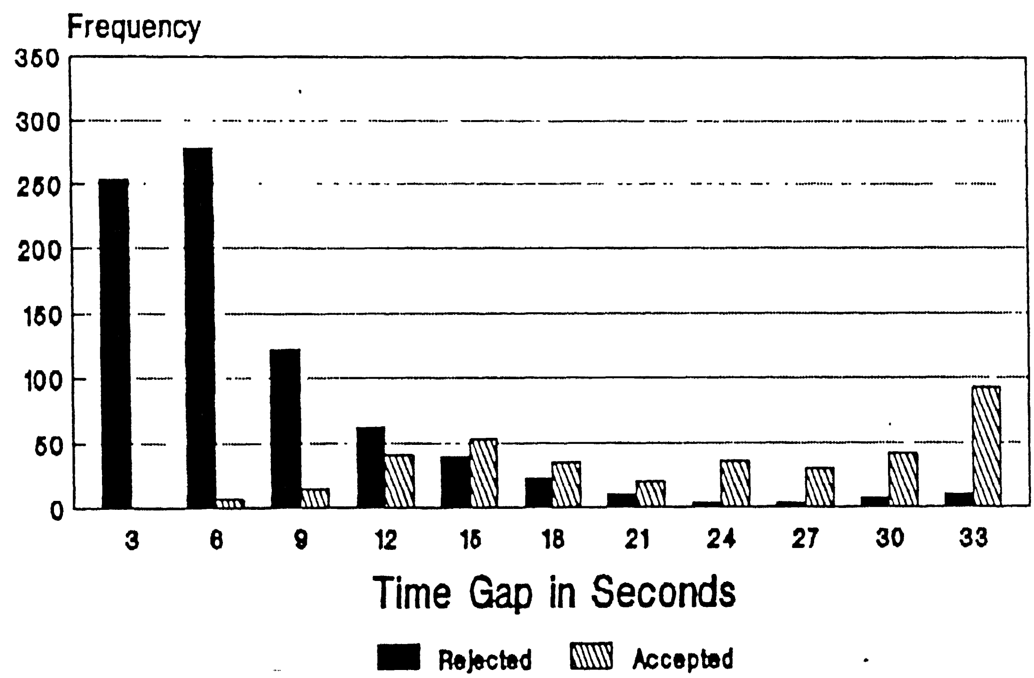


Fig. 5.24 Frequency Distribution of Rejected / Accepted Opportunities for All Vehicles

5.6.2 PROBABILITY OF GAP ACCEPTANCE

The proportion of gaps accepted is a ratio of the number of accepted gaps in a particular range (say t to t+ Δt) to the total number of gaps offered to the drivers in the same range. The proportion of accepted gaps is very low for small gaps and very high for large gaps . This is so because all large gaps would be accepted by drivers.

The frequency distributions of rejected and accepted gaps are determined for both time and space gaps. The available time gap to oncoming vehicle from test vehicle is affected by the speed of oncoming vehicle, but the available space gap is not affected by the speed of oncoming vehicle. The decision of driver to start an overtaking manoeuvre is dependent upon the speed of oncoming vehicle. The analysis, considering the time gaps, will definitely be close to reality. However the analysis, in this study, is done for both time and space gaps.

The probability of accepting a gap is determined from the frequency distributions of accepted and rejected gaps. The proportion of gap acceptance is equal to zero for small gaps and almost 100 percent for large gaps. The relationship between the proportion of gap accepted and the gap size is a probabilistic function. Based on the observed proportion of acceptance for different gap sizes, it is proposed to establish a mathematical relationship to estimate the probability of overtaking for a gap size. It is observed that upto a certain gap size there is no

acceptance. As the gap size increases the probability of acceptance also increases, but beyond a certain large gap size, there is no change in the probability of gap acceptance.

For some vehicles the maximum probability may be equal to one whereas in some other groups, there may be some drivers who may not overtake even when sufficient large gap size is available. As the objective of this study was to capture more number of observations, the test vehicle was driven at relatively slow speed over long stretch so that most of the vehicles with higher desire speed would prefer to overtake the test vehicle.

In the first phase of traffic simulation study (CRRI,1985), probability of gap acceptance was considered to follow a linear relationship with gap size. The observations in the present study show that the linear relationship is not appropriate, but a polynomial is found to be a better fit according to the observations. The following relationship is established.

$$P(x) = a + bx + cx^2 \qquad \ldots (5.1)$$

Where

P(x) - Probability, in percent, of accepting the gap of size x

a,b,c - Coefficients.

The above relationship is subject to certain constraints for threshold gaps. A certain minimum gap, S_1 , is needed for accepting any overtaking opportunity. Hence any gap less than S_1

is rejected by all vehicles of the group. There is also a threshold upper gap size, S_2 ,which has the highest probability of overtaking. Any gap larger than S_2 will have the same probability to overtake. Between S_1 and S_2 gap sizes, it is found that polynomial of second order is the best fit. The form of the gap acceptance probability is shown in Fig. 5.25 and has following mathematical relationship

$$P(x) = 0 \qquad \text{for } x \leq S_1 \qquad \ldots(5.2)$$

$$P(x) = a + bx + cx^2 \qquad \text{for } S_1 < x \leq S_2 \qquad \ldots(5.3)$$

$$P(x) = a + bS_2 + aS_2^2 \qquad \text{for } x > S_2 \qquad \ldots(5.4)$$

$$= P_{max}$$

Where

$P(x)$ = Probability, in percent,of accepting the gap of size x

Pmax = Highest probability of gap acceptance

S_1 = Minimum threshold gap for overtaking manoeuvre

S_2 = Maximum threshold gap for overtaking manoeuvre

a, b and c = Coefficients

The relationships between probability of gap acceptance and gap sizes are shown in Figs. 5.26 - 5.31.

- For different type of overtaking vehicle
- Type of overtaking (Flying/Accelerative)
- Type of Terrain (plain/Rolling)

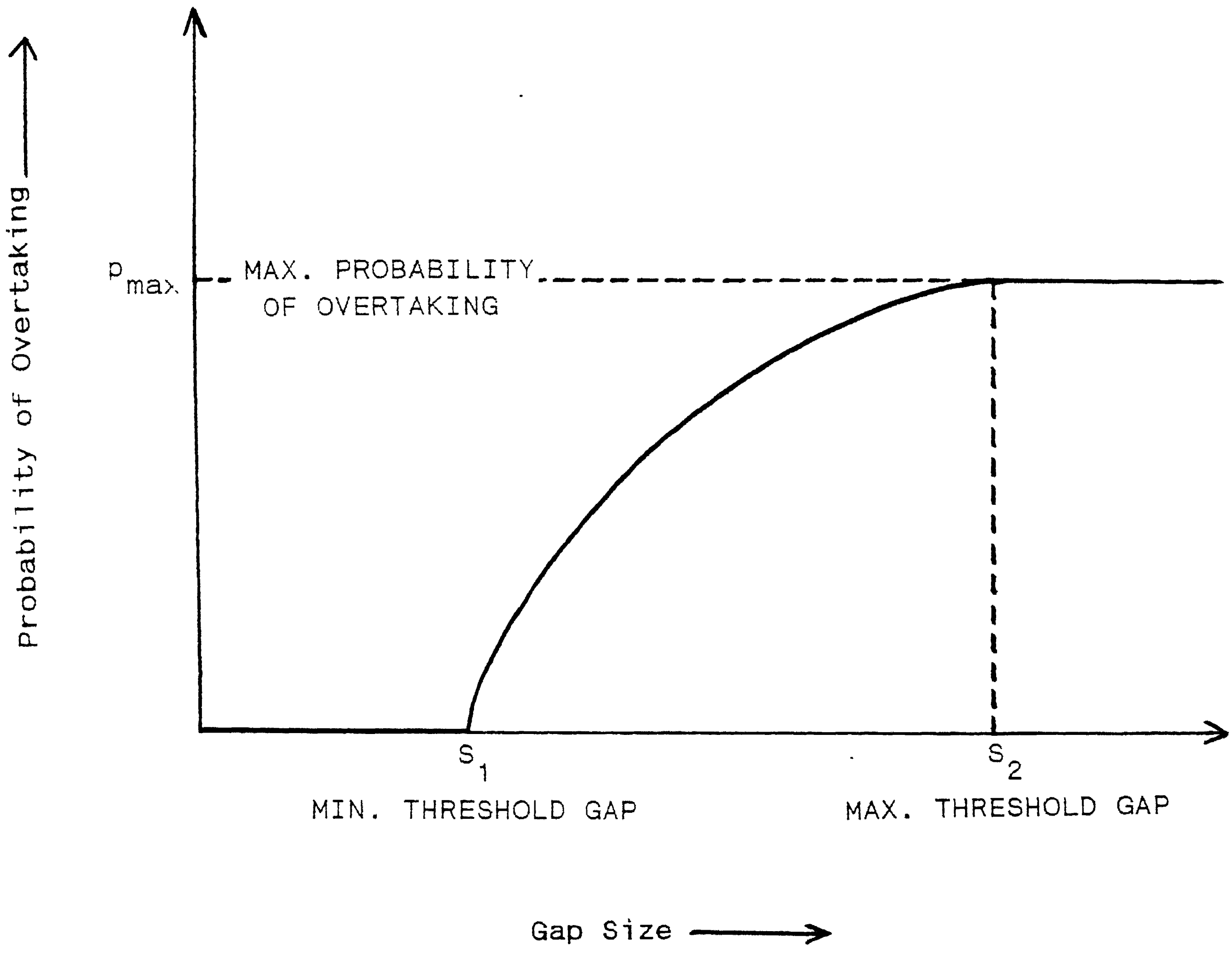


Fig. 5.25 : GAP ACCEPTANCE RELATIONSHIP

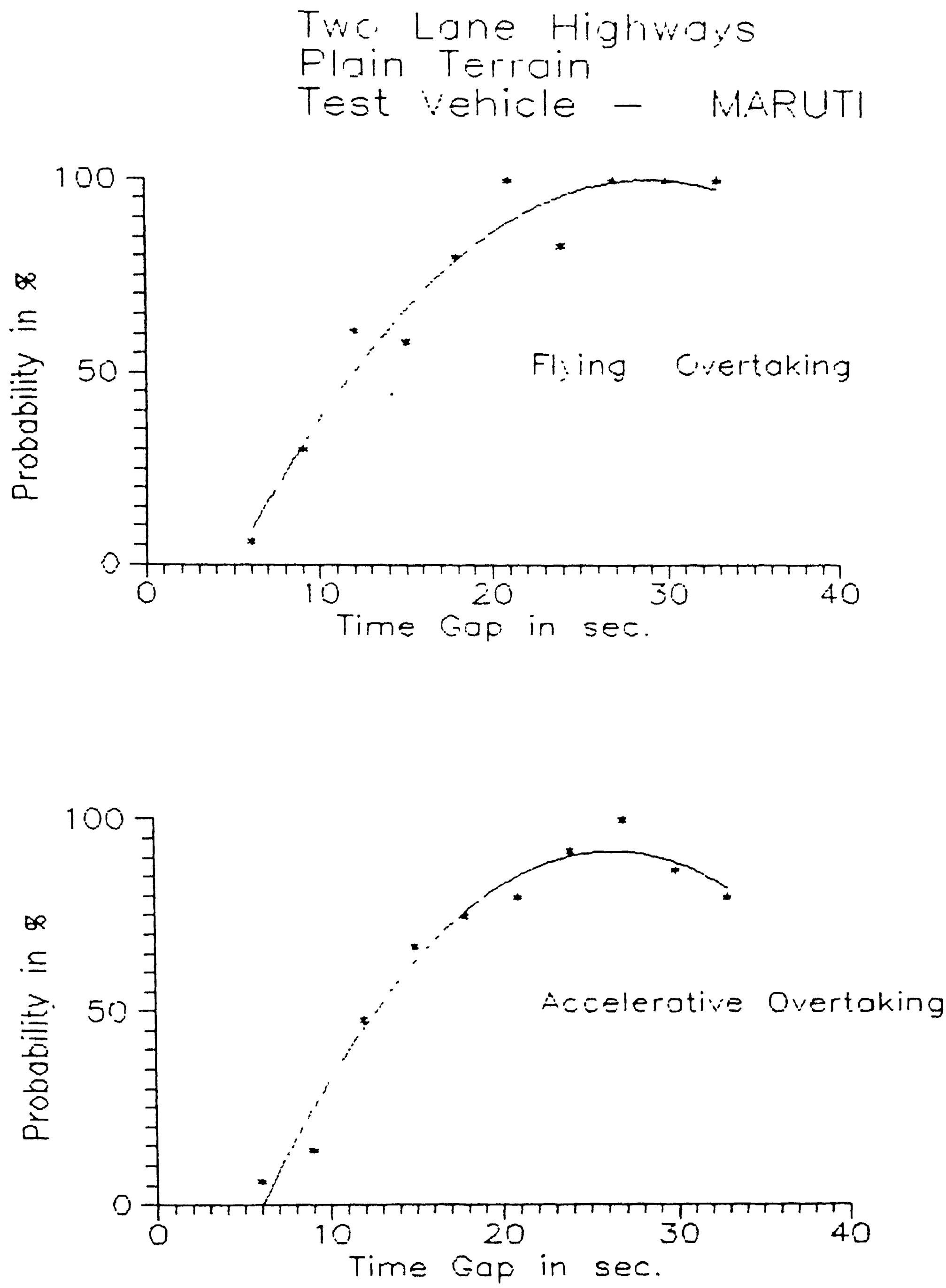


Fig. 5.26 Probability of Gap Acceptance by Maruti

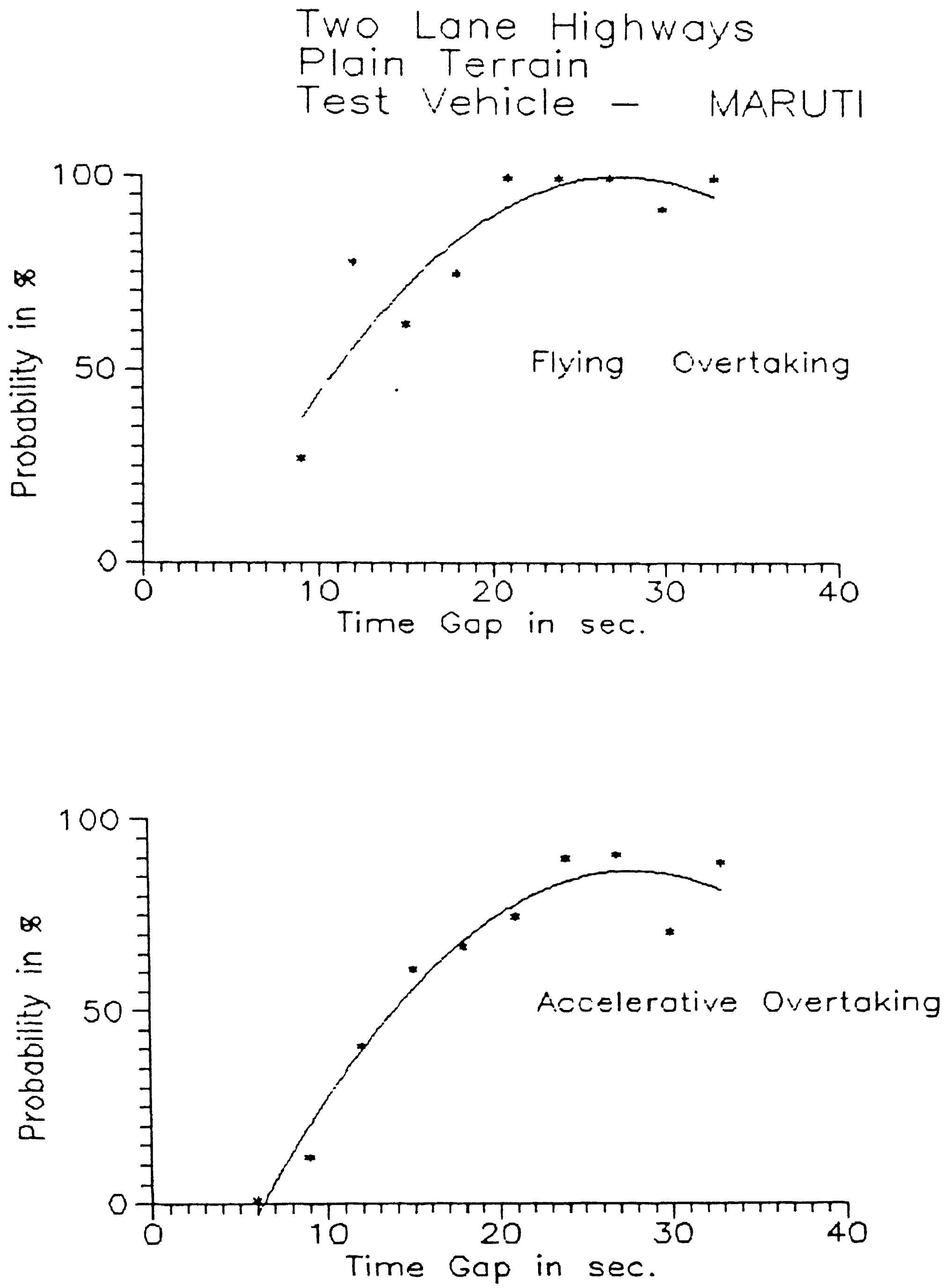


Fig. 5.27 Probability of Gap Acceptance by Other Cars

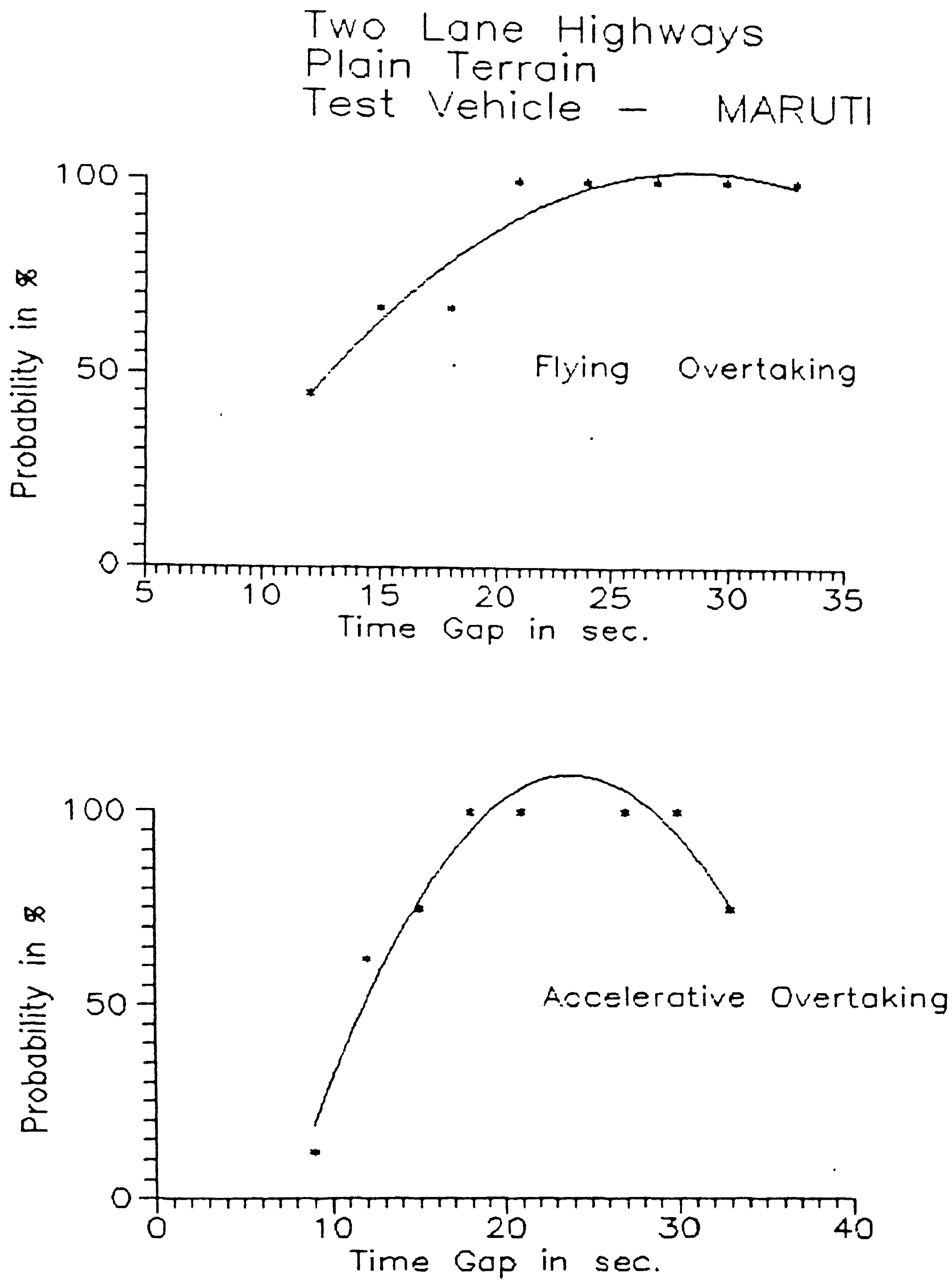


Fig. 5.28 Probability of Gap Acceptance by L.C.V.

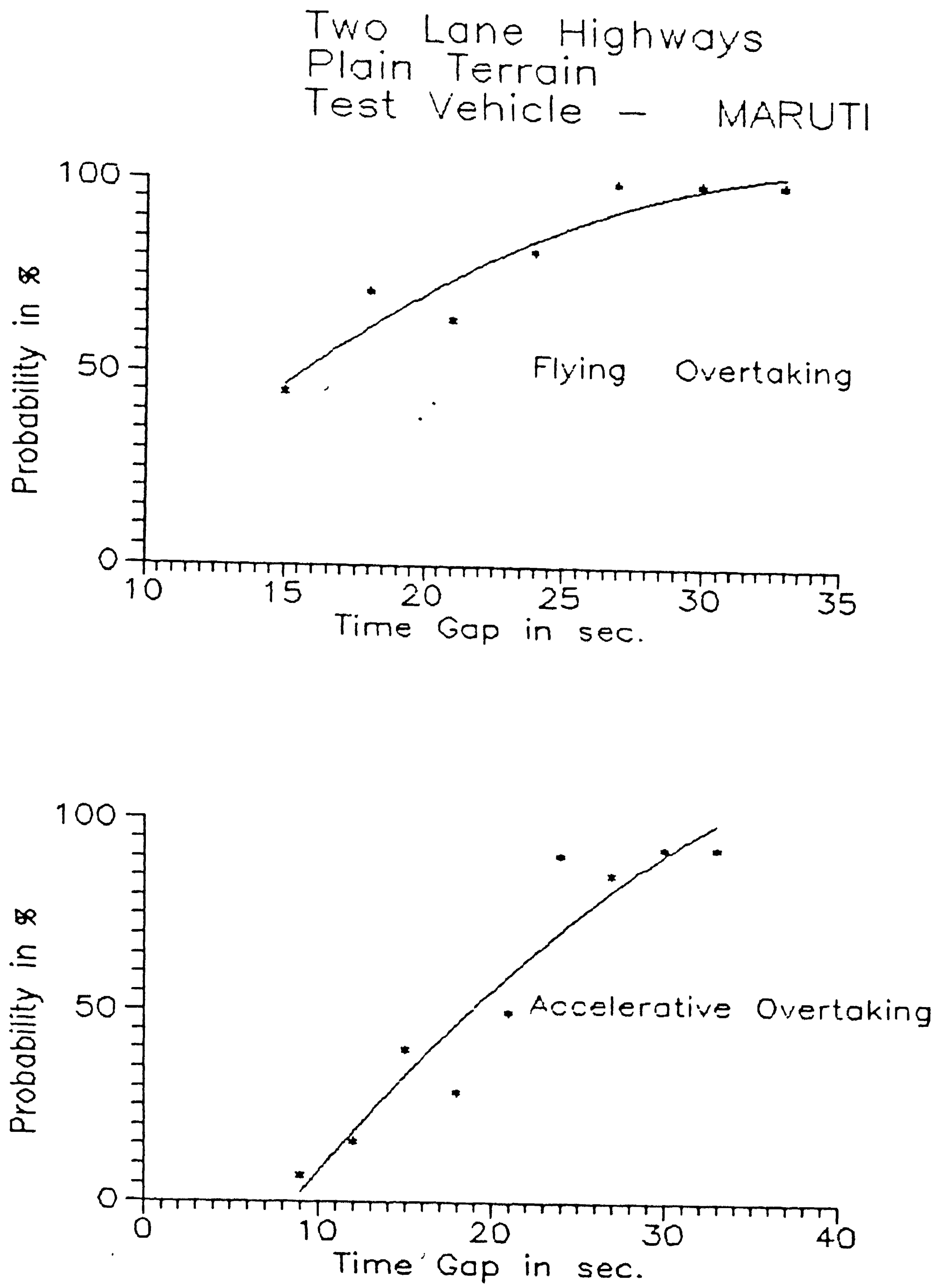
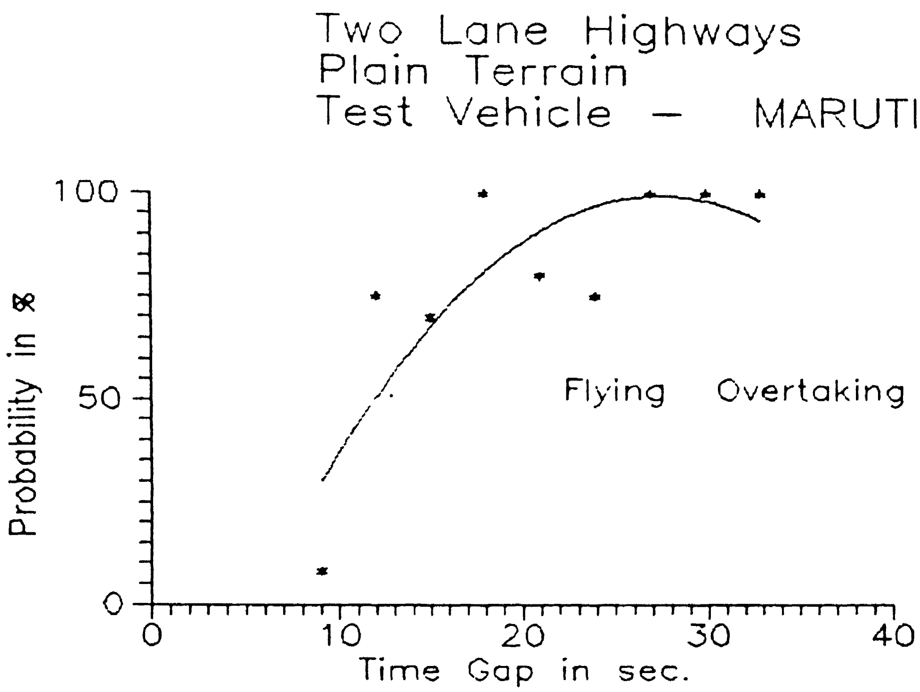


Fig. 5.29 Probability of Gap Acceptance by Truck



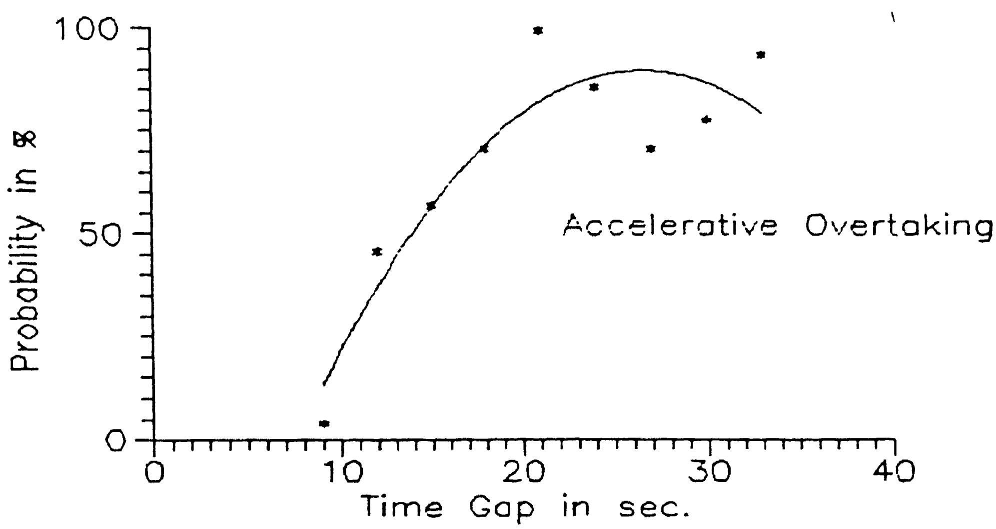


Fig. 5.30 Probability of Gap Acceptance by Bus

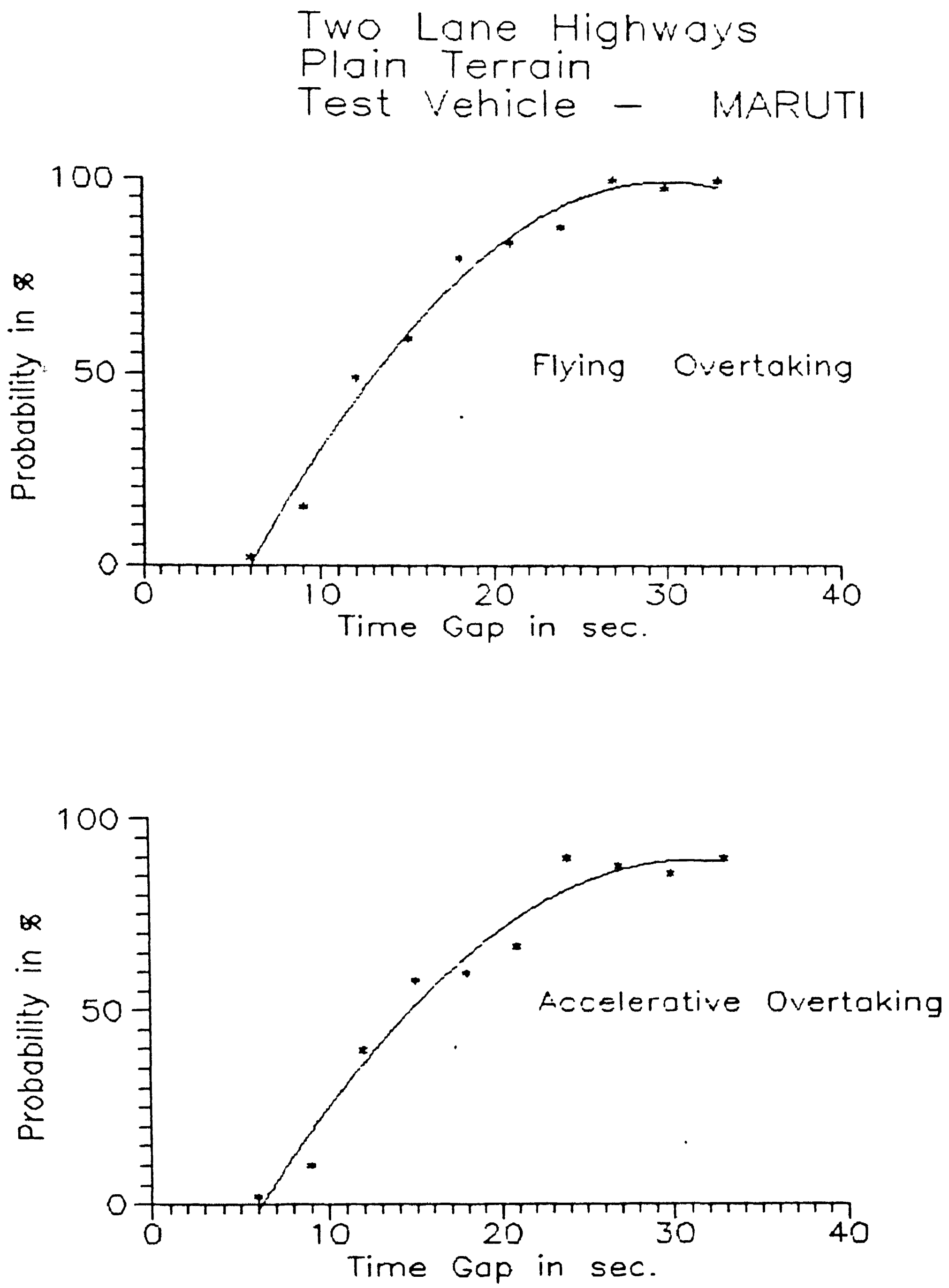


Fig. 5.31 Probability of Gap Acceptance by All Vehicles

The established second order polynomials explain a very high percent of residuals about the mean. In most of the cases, the relationships explain above 90 percent of the residual about the mean (Tables 5.16 - 5.17).

The maximum probability of overtaking large gaps is very close to 100 percent in most of the cases. The minimum threshold gap size varies from 4 to 8 seconds depending upon the type of overtaking vehicle. The minimum threshold space gap lies between 100 and 250 meters. The values of the highest threshold gap size beyond which there is no change in the probability of overtaking, are also presented in Tables 5.16 - 5.17. These gaps vary between 20 and 33 second depending upon the terrain and type of overtaking vehicle. It is observed that the maximum threshold gaps are about 2 to 3 seconds higher in plain terrain as compared to rolling terrain for all vehicle types. It may be worth mentioning that the sample sizes of the overtaking vehicles are very much different for each vehicle type. This may slightly affect the values of the regression coefficients, but on the whole the established relationships are quite realistic for use in Traffic Simulation Modelling.

TABLE 5.16 : TIME GAP ACCEPTANCE RELATIONSHIPS

Type of Vehicle	Type of Overtaking	Regression Coefficients (a)	(b)	(c)	Percent of residuals explained	Threshold Gaps Min. (S1)	Max. (S2)	Maximum Prob. (percent
PLAIN TERRAIN								
MARUTI	Fly.	-44.8000	9.98182	-0.1717170	95	5	28	100
	Acc.	-62.7318	11.71490	-0.2218010	97	6	26	92
OTHER CARS	Fly.	-39.0628	10.11870	-0.1833810	82	4	26	100
	Acc.	-58.8288	10.46840	-0.1881310	95	6	28	87
L.C.V.	Fly.	-69.9107	12.06940	-0.2109790	92	7	26	100
	Acc.	-123.4130	19.47970	-0.4075380	96	8	20	100
TRUCKS	Fly.	-61.5714	9.11508	-0.1256610	91	8	31	100
	Acc.	-51.1593	6.49949	-0.0583213	90	9	33	100
BUS	Fly.	-54.3446	11.17070	-0.2027420	70	5	28	100
	Acc.	-86.1139	13.28230	-0.2502410	84	8	26	90
ALL VEHICLES	Fly.	-56.3091	10.35150	-0.1717170	98	6	30	100
	Acc.	-49.8424	8.88283	-0.1414140	97	6	31	90
ROLLING TERRAIN								
MARUTI	Fly.	-44.1087	12.28690	-0.2570950	75	4	21	100
	Acc.	-21.2623	9.68182	-0.1853220	84	3	21	100
OTHER CARS	Fly.	-71.0682	12.63360	-0.2276940	95	6	24	100
	Acc.	-35.1833	8.08207	-0.1199490	80	5	31	100
L.C.V.	Fly.	-164.2420	21.56570	-0.4208750	81	9	21	100
	Acc.	-36.1250	9.16667	-0.1527780	100	4	27	100
TRUCKS	Fly.	-90.9643	13.22620	-0.2314810	86	8	28	98
	Acc.	-39.7679	5.77579	-0.0416667	93	8	29	98
BUS	Fly.	-60.3333	11.32440	-0.1980820	68	6	26	100
	Acc.	-35.2247	9.15232	-0.1595060	55	4	29	96
ALL VEHICLES	Fly.	-72.5333	12.62020	-0.2289560	96	7	26	100
	Acc.	-24.0788	5.89417	-0.0608651	98	4	31	100

TABLE 5.17 : SPACE GAP ACCEPTANCE RELATIONSHIPS

Type of Vehicle	Type of Overtaking	Regression Coefficients (a)	(b)	(c)	Percent of residuals explained	Threshold Gaps Min. (S1)	Max. (S2)	Maximum Prob. (percent)
PLAIN TERRAIN								
MARUTI	Fly.	-44.8288	0.318508	-0.000173864	96	150	850	100
	Acc.	-37.0848	0.258273	-0.000137879	89	150	925	84
OTHER CARS	Fly.	-57.5848	0.386106	-0.000232576	76	175	725	100
	Acc.	-54.8091	0.285924	-0.000141667	90	200	1000	89
L.C.V.	Fly.	-61.0952	0.333214	-0.000172619	72	200	1000	100
	Acc.	-156.9220	0.669348	-0.000428463	90	275	700	100
TRUCKS	Fly.	-81.7143	0.397619	-0.000216667	80	225	875	100
	Acc.	-47.6212	0.232167	-0.000096212	91	225	1100	91
BUS	Fly.	-97.1719	0.467364	-0.000268831	89	250	725	100
	Acc.	-53.8100	0.278530	-0.000148593	58	225	950	77
ALL VEHICLES	Fly.	-64.9894	0.374826	-0.000210985	95	200	825	100
	Acc.	-33.1333	0.221706	-0.000102331	94	175	1075	87
ROLLING TERRAIN								
MARUTI	Fly.	-5.89394	0.256212	-0.000154545	96	50	800	100
	Acc.	-18.65690	0.251818	-0.000129827	83	75	825	100
OTHER CARS	Fly.	-50.13480	0.374159	-0.000223106	79	150	675	100
	Acc.	-43.52112	0.314636	-0.000174242	87	150	900	98
L.C.V.	Fly	-5.76989	0.247208	-0.000137617	98	50	725	100
	Acc.	-139.23300	0.502999	-0.000260087	85	350	850	100
TRUCKS	Fly.	-47.80650	0.350288	-0.000202706	84	150	750	100
	Acc.	-46.24090	0.272295	-0.000123864	94	175	950	100
BUS	Fly.	-38.87580	0.366409	-0.000226515	84	125	625	100
	Acc.	-96.87070	0.611512	-0.000480765	78	175	625	97
ALL VEHICLES	Fly.	-35.49090	0.325853	-0.000190559	91	125	725	100
	Acc.	-31.27270	0.250699	-0.000120280	96	125	1050	100

6. SUMMARY AND CONCLUSIONS

6.1 BACKGROUND

The overtaking on two-lane roads is highly complex, involving time, speed and distance variables. However, basically it is greatly restricted by both available sight distance and traffic volume. For a driver to initiate and complete an overtaking manoeuvre, he must be able to judge whether it is safe to do so. The most important decision he must make is whether there is sufficient clear roadway ahead so that he may travel in the opposite lane until his position is ahead of the vehicle he wishes to pass.

The opportunity for overtaking is a function of the supply of overtaking opportunities provided by highway geometry and gaps adequate for overtaking in the oncoming traffic stream. The supply of overtaking opportunities is more or less fixed when compared to the demand for overtaking which is determined by the characteristics of drivers and vehicles and varies in time and space. The demand for overtaking is a function of the characteristics of drivers and vehicles. Demand also varies in time and space.

The Indian traffic system is extremely heterogeneous and highly complex and it is very difficult to express the speed flow relationships unless interactions between vehicles are studied in detail, for which the formulation of realistic simulation models is imperative.

speed of oncoming vehicle with respect to the test vehicle, is fitted near the driver facing the traffic in front of the test vehicle. The speedometer of test vehicle is also connected to the video system. The whole system is kept in such a way that it is not visible to the drivers of the other vehicles in the traffic.

The video recording of the overtaking operations was carried out by C.R.R.I. New Delhi with Maruti Van as the Test Vehicle. For this analysis, 25 cassettes for plain and 18 cassettes for rolling terrain are available.

In the light of the various events identified for the overtaking manoeuvre, a proforma is designed for primary recording of video data. The recorded video tapes are analysed in the laboratory to get primary data for each overtaking manoeuvre. The events are recorded on the proforma.These primary data are scanned to be used for analysing the characteristics of the overtaking and for estimating the various parameters.

A computer program (TESTING) is developed to locate various errors and inconsistencies. The testing is done separately for each file of a video cassette. After complete validation of the data, the files are merged to make two groups one for plain terrain and other for rolling terrain.

The primary data is used to calculate the value of the derived parameters which quantify the overtaking manoeuvre. The derived parameters of primary interest in this study are:

(i) Oncoming gap for rejected opportunities.

(ii) Oncoming gap for accepted opportunities.

(iii) Gap for catch-up position.

(iv) Gap at start of overtaking.

(v) Gap from start to level-up point.

(vi) Gap from level-up to end of overtaking.

(vii) Gap from start to end of overtaking.

(viii) Gap between end of overtaking and oncoming vehicle/ sight obstruction.

Most of the parameters involve estimation of the gaps in the overtaking manoeuvre. These gaps may be defined both in terms of time and distance. Time gaps are more accurately determined from observed data. Inspite of these deficiencies the gaps are calculated both in terms of time and distance. The values of all the derived parameters are analysed separately for time gap and space gap measurements

6.3 DATA ANALYSIS

The analysis of the overtaking manoeuvre was carried out in following ways:

(a) Study the nature of different derived parameters. This analysis helps to identify the general nature and to plan for other type of analysis.

(b) Analysis of the statistics for the derived parameters. This is planned at various disaggregated levels.

(c) Study of rejected/accepted opportunities and to compute the probability of gap acceptance.

The analysis involves the development of a number of computer program. The emphasis is also laid on the graphical display of the statistics for different parameters.

It is seen that the sample size of the overtaking manoeuvre is sufficiently large for statistical analysis. The total number of flying and accelerative overtaking manoeuvres for plain terrain are very close to each other, being 393 and 371 respectively. But for rolling terrain, the number of flying overtaking are much larger than accelerative ones,being 319 and 150 respectively.

6.3.1 NATURE OF DERIVED PARAMETERS (PROGRAM ANALYSIS I)

The program ANALYSIS I determines the frequency distributions for each of the parameters. This information is input for a display program which provides online graphic display of different parameters.These illustrations show that there is a wide dispersion amongst the values of different parameters. The dispersions are generally left skewed and skewed to right for some of the parameters.

6.3.2 STATISTICS OF DERIVED PARAMETERS (PROGRAM ANALYSIS II)

The eight derived parameters as analysed in this study can be classified into two groups:

(i) Decision Parameters : These parameters contribute to the decision about the rejection or acceptance of an overtaking opportunity. These include the gaps for accepted and rejected opportunities.

(ii) Performance Parameters : These parameters describe the performance while executing an overtaking operation.

Results for the oncoming time gaps for accepted opportunities show that the mean acceptable time gaps are higher for flying overtaking by about 2 to 4 seconds than those for the accelerative overtaking operations. This is because a following vehicle moving at slower speed is constantly on the look out for overtaking, and tends to accept smaller gaps. However, acceptable space gaps are almost close both for flying and accelerative overtaking. Mean acceptable time gaps depend upon the type of vehicle executing the overtaking. These gaps are maximum for Trucks and minimum for Maruti Cars. For light vehicles like Cars, L.C.V.etc., acceptable time gaps for plain terrain are lower than those for the rolling terrain, whereas for heavy vehicles like Trucks and Buses the effect of terrain is insignificant.

The mean rejected time gap varies from 5 to 8 seconds for different vehicle types. The rejected time gap distributions depend upon the traffic volume of oncoming traffic stream. It may be desirable to evaluate the critical time gaps which are rejected most often by different vehicle types. This analysis is not carried out in this study.

When a vehicle catches up, gaps are estimated with respect to the test vehicle. These gaps also depend upon the vehicle types, being highest for Trucks and lowest for Maruti Cars. For rolling

terrain, these gaps are higher than those for the plain terrain as the speed gets reduced.

The gaps while following depend upon the type and speed of the vehicle being followed. The results indicate that vehicles maintain a mean headway of about 1.5 seconds.

The result of time gaps to execute the overtaking, from start to end of overtaking, shows that the mean time gaps for overtaking manoeuvre varies from 10 to 18 seconds depending upon the vehicle types and type of overtaking. These gaps are again more for the heavy vehicles. The total gap to execute overtaking is further divided in two components namely; from start to level up point and from level up to end of overtaking.

The result of gaps for the safety margin, that is, from the instant of end of overtaking operation to the instant when oncoming obstruction crosses, indicates that light vehicles have less safety margin as because of their easy manoeuvreability these vehicle can take more risk.

The statistics for various derived parameters of different vehicle types as explained above could be used in designing the road geometries like stopping and overtaking sight distances.

6.3.3 STUDY OF GAP ACCEPTANCE (PROGRAM ANALYSIS III)

The probability of accepting a gap is determined from the frequency distributions of accepted and rejected gaps. The proportion of gap acceptance is equal to zero for small gaps and almost 100 percent for large gaps. The relationship between the

proportion of gap accepted and the gap size is a probabilistic function. Based on the observed proportion of acceptance for different gap sizes, a mathematical relationship is established to estimate the probability of overtaking for a gap size. It is observed that upto a certain gap size there is no acceptance. As the gap size increases the probability of acceptance also increases, but beyond a certain large gap size, there is no change in the probability of gap acceptance. The form of the gap acceptance probability has following mathematical relationship

$$P(x) = 0 \qquad \text{for } x \leq S_1$$

$$P(x) = a + bx + cx^2 \qquad \text{for } S_1 < x \leq S_2$$

$$P(x) = a + bS_2 + as_2^2 \qquad \text{for } x > S_2$$

$$= P_{max}$$

Where

$P(x)$ = Probability, in percent, of accepting the gap of size x

Pmax = Highest probability of gap acceptance

S_1 = Minimum threshold gap for overtaking manoeuvre

S_2 = Maximum threshold gap for overtaking manoeuvre

a, b and c = Coefficients

The established second order polynomials explain a very high percent of residuals about the mean. In most of the cases, the relationships explain above 90 percent of the residual abcut the mean.

The maximum probability of overtaking large gaps is very close to 100 percent in most of the cases. The minimum threshold gap size varies from 4 to 8 seconds depending upon the type of overtaking vehicle. The minimum threshold space gap lies between 100 and 250 meters. The values of the highest threshold gap size beyond which there is no change in the probability of overtaking, vary between 20 and 33 second depending upon the terrain and type of overtaking vehicle. It is observed that the maximum threshold gaps are about 2 to 3 seconds higher in plain terrain as compared to rolling terrain for all vehicle types. The established relationships are quite realistic for use in Traffic Simulation Modelling.

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